IMPERIAL INSTITUTE
— LIBRARY —
11 APR 1939
SERIAL As. 60 D
SEPARATE

ICAR. 5. IX-1.
800

Vol. IX, Part I

February, 1939

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority

of

The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 24s.

Price per part
Rs. 3 or 5s.

Published by the Manager of Publications, Delhi
Printed by the Manager, Government of India Press, New Delhi
1939

List of Agents in India from whom Government of India Publications are available.

(*a*) PROVINCIAL GOVERNMENT BOOK DEPOTS.

MADRAS :—Superintendent, Government Press, Mount Road, Madras.
BOMBAY :—Superintendent, Government Printing and Stationery, Queen's Road, Bombay.
SIND :—Manager, Sind Government Book Depot and Record Office, Karachi (Sadar).
UNITED PROVINCES :—Superintendent, Printing and Stationery, U. P., Allahabad.
PUNJAB :—Superintendent, Government Printing, Punjab, Lahore.
CENTRAL PROVINCES :—Superintendent, Government Printing, Central Provinces, Nagpur.
ASSAM :—Superintendent, Assam Secretariat Press, Shillong.
BIHAR :—Superintendent, Government Printing, P. O. Gulzarbagh, Patna.
NORTH-WEST FRONTIER PROVINCE :—Manager, Government Printing and Stationery, Peshawar.
ORISSA :—Press Officer, Secretariat, Cuttack.

(*b*) PRIVATE BOOK-SELLERS.

Advani & Co., The Mall, Cawnpore.
Aero Stores, Karachi.*
Banthiya & Co., Ltd., Station Road, Ajmer.
Bengal Flying Club, Dum Dum Cantt.*
Bhatia Book Depot, Saddar Bazar, Ranikhet.
Bhawnani & Sons, New Delhi.
Bombay Book Depot, Charni Road, Girgaon, Bombay.
Book Company, Calcutta.
Booklover's Resort, Taikad, Trivandrum, South India.
Burma Book Club, Ltd., Rangoon.
Butterworth & Co. (India), Ltd., Calcutta.
Cambridge Book Co., Booksellers, New Dak Bungalow Road, Patna.
Careers, Mohini Road, Lahore.
Chatterjee & Co., 3, Bacharam Chatterjee Lane, Calcutta.
Chukervertty, Chatterjee & Co., Ltd., 13, College Square, Calcutta.
City Book Club, 98, Phayre Street, Rangoon.
Das Gupta & Co., 54/3, College Street, Calcutta.
Dastane Brothers, Home Service, 456, Raviwar Peth, Poona 2.
Delhi and U. P. Flying Club, Ltd., Delhi.*
Deshmukh Book Depot, Station Road, Sholapur.
Educational Book Depot, Mahal Road, Nagpur.
English Book Depot, Ferozepore.
English Book Depot, Taj Road, Agra.
English Bookstall, Karachi.
English Book Store, Abbottabad, N.-W. F. P.
Faqir Chand Marwah, Peshawar Cantonment.
Gautama Brothers & Co., Ltd., Meston Road, Cawnpore.
Higginbothams, Madras.
Hindu Library, 137/F, Balaram De Street, Calcutta.
H. L. College of Commerce, Co-operative Stores, Ltd., Ahmedabad.
House of Knowledge, Booksellers and Publishers, Palliagraharam P. O., Tanjore.
Hyderabad Book Depot, Chaderghat, Hyderabad (Deccan)
Ideal Book Depot, Rajpur Road, Dehra Dun.
Imperial Book Depot and Press, near Jama Masjid (Machhliwalan), Delhi.
Imperial Publishing Coy., Lahore.
Indian Army Book Depot, Dayalbagh, Agra.
Indian Army Book Depot, Daryaganj, Delhi.
Indian Book Shop, Benares City.
Indian School Supply Depot, Central Avenue, South P. O. Dharamtala, Calcutta.
Insurance Publicity Co., Ltd., Lahore.
International Book Service, Poona 4.
Jaina & Bros., Mori Gate, Delhi, and Connaught Place, New Delhi, Messrs. J. M.
Kamala Book Depot, 15, College Square, Calcutta.
Keale & Co., 65, Britto Road, Karachi (Sadar).
Keshno Book Stall, Khadibazar, Belgaum.
Kitabistan, 17-A, City Road, Allahabad.
Krishnaswami & Co., Teppakulam P. O., Trichinopoly Fort, Messrs. S.
Lahiri & Co., Ltd., Calcutta, Messrs. S. K.
Local Self-Govt. Institute, Bombay.
London Book Co. (India), Arbab Road, Peshawar, Murree, Nowshera, Rawalpindi.
Mackwin & Co., Booksellers, Stationers and News Agents: Inverarity Road, off Esphenstone Street, Karachi Sadar.
Malhotra & Co., Post Box No. 94, Lahore, Messrs. U. P.
Malik & Sons, Sialkot City.
Mathur & Co., Messrs. B. S., Chatur-Vilas, Paota, Civil Lines, Jodhpur (Rajputana).
Minerva Book Shop, Anarkali Street, Lahore.
Modern Book Depot, Bazar Road, Sialkot Cantonment.
Mohanlal Dossabhai Shah, Rajkot.
Mohendra Bros. Lashkar, Gwalior State, Messrs.
Nandkishore & Bros., Chowk, Benares City.
New Book Co., "Kitab Mahal", 192, Hornby Road, Bombay.
Newman & Co., Ltd., Calcutta, Messrs. W.
Oxford Book and Stationery Company, Delhi, Lahore, Simla, Meerut and Calcutta.
Parikh & Co., Baroda, Messrs. B.
Pioneer Book Supply Co., 20, Shib Narayan Das Lane, Calcutta and 219, Cloth Market, Delhi.
Popular Book Depot, Grant Road, Bombay.
Punjab Religious Book Society, Lahore.
Raghunath Prasad & Sons, Patna City.
Rama Krishna & Sons, Booksellers, Anarkali, Lahore.
Ram Krishna Bros., Opposite Bishrambag, Poona City.
Ram Narain Lal, Katra, Allahabad.
Ramesh Book Depot and Stationery Mart, Kashmere Gate, Delhi.
Ray & Sons, 43, K. & L. Edwardes Road, Rawalpindi, Murree and Peshawar, Messrs. J.
Roy Chowdhury & Co., 72, Harrison Road, Calcutta, Messrs. N. M.
Saraswati Book Depot, 15, Lady Hardinge Road, New Delhi.
Sarcar & Sons, 15, College Square, Calcutta, Messrs. M. C.
Sarkar & Co., Ltd., 18, Shama Charan De Street, and 6 Hastings Street, Calcutta, Messrs. P. C.
Sharada Mandir Ltd., Nai Sarak, Delhi.
Standard Bookstall, Karachi.
Standard Bookstall, Quetta.
Standard Book Depot, Lahore, Dalhousie and Delhi.
Standard Law Book Society, 69, Harrison Road, Calcutta.
Tara & Sons, Razmak (India), Messrs. B. S.
Taraporevala Sons & Co., Bombay, Messrs. D. B.
Thacker & Co., Ltd., Bombay.
Thacker, Spink & Co., (1933), Ltd., Calcutta.
Tripathi & Co., Booksellers, Princes Street, Kalbadevi Road, Bombay, Messrs. N. M.
Uberoy, J. C., Journalist, Printer and Publisher, Jaycee House, Alexandra Road, Ambala.
Universal Book Depot, 58, Hazratganj, Lucknow.
University Book Agency, Kacheri Road, Lahore.
Upper India Publishing House, Ltd., Literature Palace, Ammuddaula Park, Lucknow.
Varadachary & Co., Madras, Messrs. P.
Venkatasubban, A., Law Bookseller, Vellore.
Wheeler & Co., Allahabad, Calcutta and Bombay Messrs. A. H.
Young Man & Co. (Regd.), Egerton Road, Delhi.

*Agent for publications on Aviation only.

CONTENTS

(Vol. IX, Part I)

February, 1939

The Editorial Committee of the Imperial Council of Agricultural Research India, takes no responsibility for the opinions expressed in this Journal.

Original Articles—

		Page
Studies in the Rind-hardness of Sugarcane, I. Anatomy of the Stalk and Rind-hardness (with Plate I and two text-figures)	*K. L. Khanna and Rama Rao Panje*	1
A Statistical Study of the Loss caused by Borers and Termites to Mature Sugarcane at Pusa in 1935 and 1936 (with one text-figure)	*H. S. Pruthi, M.Sc., Ph.D. (Cantab.), F.N.I. and E. S. Narayanan, M.A.*	15
The Proteins in the Rice Grain and the Development of Aleurone Layer (with Plates II-IV)	*K. Ramiah and C. Rajasekhara Mudaliar*	39
An Investigation into the Algal-flora of Paddy Field Soils of the United Provinces, I.	*Rama Nagina Singh, M.Sc.*	55
On the Probability of Seasonal Migration among the Solitary Phase Individuals of *Locusta migratoria* in North-West India (with Plate V and one map)	*Y. Ramchandra Rao, M.A., F.R.E.S. and Desraj Bhatia, M.Sc.*	79
Economics of Field-scale Spraying against the White-fly of Cotton (*Bemisia gossypiperda* M. & L.) (with one text-figure)	*M. Afzal Husain, M.A. (Cantab.), I.A.S.; Kidar Nath Trehan, M.Sc. and Piare Mohan Verma, M.Sc.*	109
Notes on the Life-history and Habits of *Dacus brevistylus* Bezzi (Family Trypetidae), a Pest of *Coccinia indica* Fruits (with Plate VI)	*M. C. Cherian, B.A., B.Sc., D.I.C. and C. V. Sundaram*	127
A Review of the Literature on the Nutritive Value of Pulses	*R. K. Pal* . . .	133

Notes—

Plant Quarantine Regulations	145
List of International Congresses and Conferences to be held during the Next Five Years	149
New Vice-President of the International Institute of Agriculture, Rome	150

ORIGINAL ARTICLES

STUDIES IN THE RIND-HARDNESS OF SUGARCANE

I. ANATOMY OF THE STALK AND RIND-HARDNESS

BY

K. L. KHANNA

AND

RAMA RAO PANJE

Sugarcane Research Scheme, Bihar

(Received for publication on 10th May 1938)

(With Plate I and two text-figures)

THE rind-hardness of sugarcane varieties has been a subject of some importance owing to the preference shown by rodents and other gnawing animals to soft-rinded canes, a problem of some concern to growers in many localities. Hard and fibrous canes, while comparatively free from pests and generally good in growth, are not readily accepted by sugar-factories and *gur*-makers, owing to comparative difficulty in milling such canes and their poorer extraction; while soft-rinded canes have to be continually guarded against the depredations of these various kinds of animals. It is intended in these studies to investigate the more important of the factors which influence the hardness of the rind.

These factors are divisible into two categories—the internal and external. The former are mainly anatomical characters which are an expression of the inherent capacity of a variety for the development of a hard rind; the latter are environmental influences which tend to modify, to a greater or less extent, the hardness resulting from the internal characters. These two aspects have been studied separately and this paper deals with the former concerning the anatomical aspect.

I. INTRODUCTION

The anatomical characters of the cane stalk form the primary basis for the development of hardness in the rind. The number of these characters is large and their various combinations appear to produce varying degrees of rind-hardness. The ideal combination of these characters would be such as would result in the development of a hard rind coupled with a soft core. Such a cane would probably be characterised by the exclusive development of those mechanical tissues only which contribute to the hardening of the rind without in any way affecting the core. The present studies were undertaken in order to identify such tissues and the mode of their most effective distribution.

II. Material and methods

The varieties selected for study were Cos 213, 285, 312, 313, 326 and 356. The hardness of the rind in the sampled material of these varieties was determined by an instrument described by Khanna [1935], which measures, by means of a spring arrangement, the force required to puncture the rind with a standard metal point of diameter 0·75 mm. About a dozen canes of each variety were selected at random from the plot and the rind-hardness of these was determined roughly by a few punches. Sub-samples of three canes per variety were selected from among these so that a fair range of hardness of the variety was represented in them ; the actual age of the shoot was not known, but the three selected canes were styled as old, medium and young, according to their hardness, for such they evidently were though not selected as such. From each of these, cross-sections of the ' basal ' joint (the joint just above the one at the ground level) and of the ' dry-leaf ' joint (the one bearing the topmost dry-leaf at the time) were cut after determining the hardness* of each of the selected joints by four punches all round the joint. When the last variety, Co 313, was being tested, unfortunately, the instrument slipped off the cane and the point jammed. As a fresh point would have been sharper and would have given erroneous readings, the old point was ground till it gave the same readings as were taken on the sampled canes before the point got damaged.

The sections were cut with a sledge-microtome out of fresh material, and stained and mounted in Canada balsam. Owing to the presence of hard and soft tissues in the same material, cross-sections less than 60 to 80μ could not be cut without mutilating the sections. In all cases, the sections were taken from the middle portion of the joint. Measurements were made under the microscope at different magnifications. An area of 2·5 sq. mm. of rind 1 mm. thick (radially) in the cross-section was taken for the necessary countings of vascular bundles, etc. The areas occupied by the tissues in the cross-section were measured on camera lucida drawings by means of a planimeter. The degree of lignification was estimated by an ocular micrometer. Considerable difficulty was felt in this determination owing to the thickness of the section, but the measurements were taken at the top focus on the section as accurately as possible, and were used only for their comparative values.

III. Investigations

In a preliminary study [Khanna, 1934] several anatomical characters had been observed and measured where possible, in order to select such among them as were really effective. Among these were :

1. The number of vascular bundles per unit area of the rind in cross-section.

*Thus the readings in the following pages represent the hardness of the particular material under observation and not necessarily the average hardness of the variety as a whole. By this means, errors due to small samples were avoided, though, it must be admitted, the value of the inferences arrived at was thereby slightly diminished for the purpose of application to the variety as a whole.

2. The size of the vascular bundles and the extent of the occurrence of the various sizes.
3. The area of vascular bundles in cross-section.
4. The area of total lignified tissues in the rind in cross-section, and the distribution of these in the outer and inner portions of the rind.
5. Character and degree of lignification of parenchyma in the rind.
6. Degree of lignification of the vascular sheath cells.
7. Rows of sub-epidermal cells and their lignification.
8. Depth of the peripheral chlorenchymatous layer.
9. Tissue tensions, etc.

Only three of these characters (the 1st, the 5th and the 6th in the above list) were found to be of major importance and a detailed study of these was taken up. It was obvious in the course of the study that in any variety, although the various anatomical factors could not operate independently of the related ones, this interdependence or mutual influence was less than could have been expected and that varieties could in most cases be highly partial to some character, to the comparative exclusion of closely related ones.

In the following pages, the three characters mentioned above have been considered one by one, and in the final part their combined effect has been discussed. The relationships are brought out only by arranging the varieties in the descending order of the intensity of the character under question and then finding out how far in a direct relationship the rind-hardness of the varieties so arranged also comes out in the same order and accounting for any possible exceptions. It follows from this that if all the characters, or at least all the major ones, are considered in their combination and the varieties arranged in a certain order of this combined effect, then the hardness of the varieties so arranged would also come out in the same order, and very possibly show a fair arithmetical relationship in ratios. In this manner, the three characters may now be examined individually.

1. Number of vascular bundles per unit area of rind in cross-section

The number of vascular bundles was determined by twelve determinations per variety, six on the basal joint and six on the ' dry-leaf ' joint. The average of these readings, calculated to a percentage of the total for all the varieties in each case, are compared (Table I) with the average rind-hardness of the joints sectioned.

TABLE I

Relation between the number of vascular bundles per unit area of the rind in cross-section, and the rind-hardness

'Dry-leaf' joint			'Basal' joint		
Variety	Average No. of vascular bundles in 1 sq. mm. of rind in cross-section (per cent of total)	Rind-hardness in lbs.	Variety	Average No. of vascular bundles in 1 sq. mm. of rind in cross-section (per cent of total)	Rind-hardness in lbs.
Co 356	21·8	18·3	Co 356	21·0	24·4
Co 285	17·8	13·0	Co 213	17·6	18·3
Co 213	16·4	11·7	Co 313	17·1	17·0
Co 312	15·5	10·4	Co 312	15·7	16·5
Co 313	18·3	13·7	Co 285	15·0	20·2
Co 326	13·6	16·8	Co 326	13·5	25·0

The close relationship between the number of vascular bundles and the rind-hardness in the case of the 'dry-leaf' joint as well as in the basal joint may be made out from the above table. Co 326 appears as a striking exception in both sections of the table, and Co 285 in the case of the basal joint alone. In these varieties, the hardness is greater than is suggested by the number of vascular bundles in them, and this, as will be seen later, is because these varieties lignify the parenchyma of their rind-region to an unusually high degree (Plate I, fig. 1). It will be noticed that Co 326 does so even at an early stage. The relationship is clearer in the case of the 'dry-leaf' joint, because lignification is usually a later development and does not seriously interfere with the influence of the other characters which are operative at that stage.

2. Lignification of the cell-walls in the vascular sheaths

The lignification of cell-walls in the vascular sheaths is one of those characters, which would appear to have a somewhat direct influence on the hardness of the rind. But as a matter of fact, it can be comparatively ineffective if it is not accompanied by its companion-character, *viz.*, the lignification of the walls of parenchymatous cells in-between the outer rows of vascular bundles. The two characters do not necessarily appear together or develop to the same

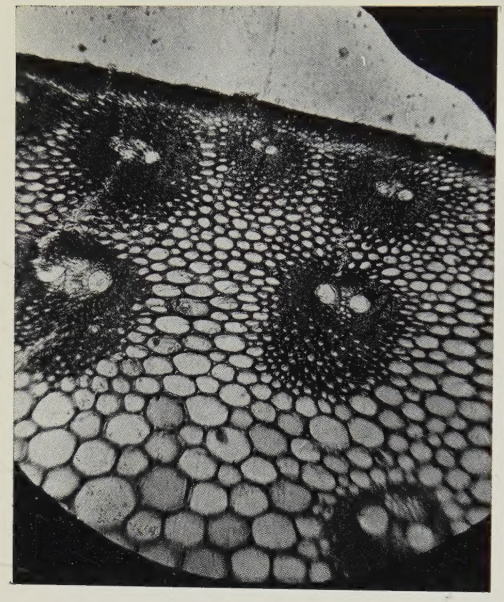


FIG. 1

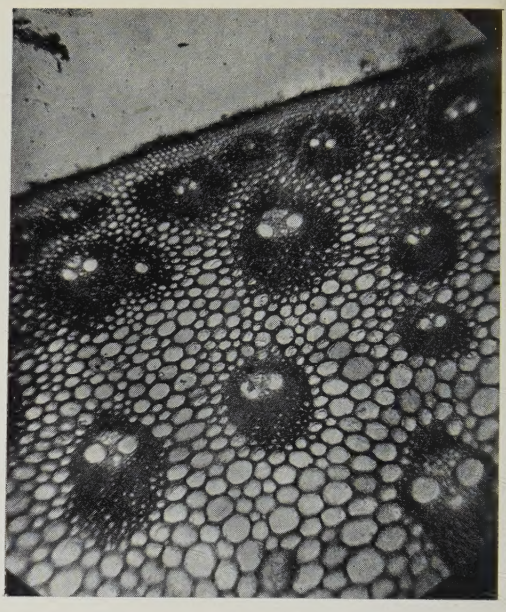


FIG. 2

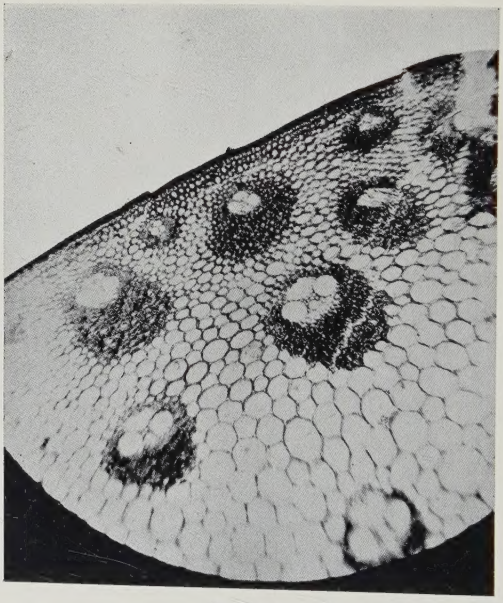


FIG. 3

FIG. 1 : Part of a cross-section through the rind portion of Co 326, showing the strong lignification of the rind tissues in general, and of the inter-vascular parenchyma in particular. The larger size of the vascular bundles, in comparison with those of Co 356 and Co 313 (FIGS. 2 and 3), is also noteworthy. FIG. 2 : Part of cross-section through rind portion of Co 356. The inter-vascular parenchyma shows adequate lignification within the rind portion. The vascular bundles are smaller in size and are more aggregated towards the periphery than they are in Co 326. The rind structure in Co 356 is thus more compact, the hardness of the rind having been attained by an "economic" distribution of lignifying tissues in the rind, rather than by any extensive lignification of parenchyma or vascular bundles as is the case in Co 326. FIG. 3 : Part of cross-section through rind portion of Co 313, showing the exclusive lignification of the vascular sheath. The inter-vascular parenchyma is poorly lignified. (*Cf.* Figs. 1 and 2). (Microphotographs, magnif. 40 dia.)

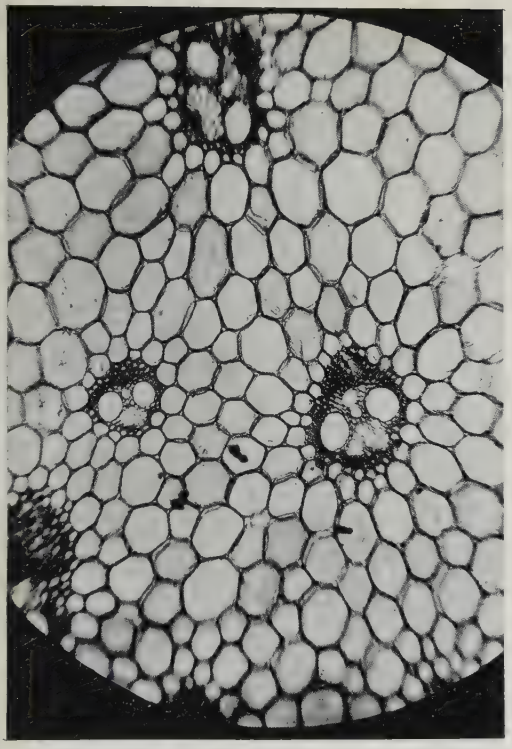


FIG. 4

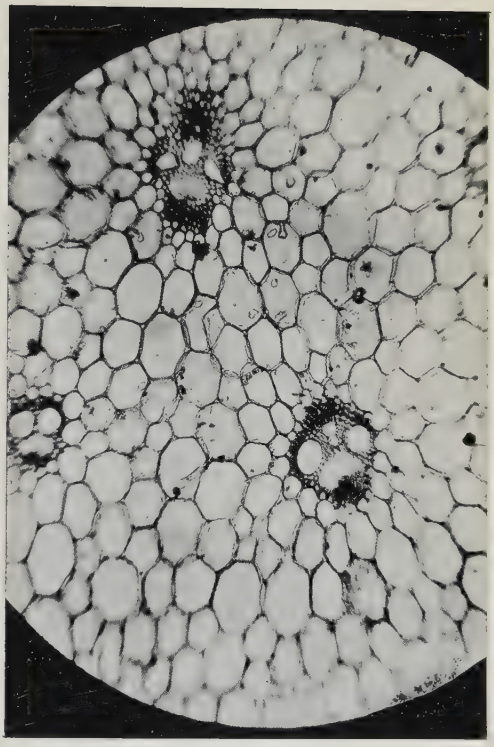


FIG. 5

FIG. 4 : Part of cross-section through stalk of Co 326, showing the maintenance of considerable lignification in the parenchyma in the interior of the stalk beyond the rind portion. This maintenance of lignification in the interior obliterates the clear demarcation of the rind in Co 326. FIG. 5 : Part of cross-section through stalk of Co 356. The lignification of the parenchyma in the interior is comparatively less than that in Co 326. The relegation of lignified tissues to the extreme periphery to form a hard and well-marked rind in Co 356 leaves the parenchyma in the interior almost unlignified, causing thereby comparatively a low fibre content in the variety. (Microphotographs, magnif. 40 dia.)

degree and this fact makes it necessary to consider them separately though they are related to and are the manifestations of the same phenomenon—the lignification of the cell-walls in the rind.

The thickness of the cell-wall (Table II) is calculated to a percentage of the total in all the varieties. Each of the figures is derived from thirty-six readings on the sheath-cells.

TABLE II

Relation between the lignification of sheath-cells of vascular bundles in the rind and the rind-hardness

'Dry-leaf' joint			Basal joint		
Variety	Lignification in sheath-cells in rind (per cent of total)	Rind-hardness in lbs.	Variety	Lignification in sheath-cells in rind (per cent of total)	Rind-hardness in lbs.
Co 326	20·8	16·8	Co 326	23·1	25·0
Co 285	18·3	13·0	Co 285	19·1	20·2
Co 313	18·1	13·7	Co 313	16·1	17·0
Co 356	15·6	18·3	Co 312	14·4	16·5
Co 312	15·1	10·4	Co 213	13·7	18·3
Co 213	12·2	11·7	Co 356	13·5	24·4

This table again shows a clear relationship between the two characters, though it includes two outstanding exceptions, Co 356 and Co 213. These two varieties appear harder in their rind than can be judged from the lignification of their vascular sheaths, and the reason is that in these two varieties, and particularly in Co 356, the number of vascular bundles is a predominating character and the varieties are more or less correspondingly weak in the lignification of the vascular sheath. A close scrutiny of Tables I and II will bear out this fact and will further show that the higher a variety occurs in Table I, the more gravely does it depart from the expected estimate of its rind-hardness in Table II. Thus, Co 356 shows unusually high numbers of vascular bundles (Table I) and the lignification of the vascular sheath being in it weaker than would be normal for it, it appears as strongly exceptional in Table II. Co 213 is less so in this respect.

3. Lignification of the inter-vascular parenchyma

The lignification of the inter-vascular parenchymatous cells is not perhaps as striking a character of the stem anatomy of sugarcane as it is in many kinds

of grasses but it is a character of considerable importance in the development of hardness in the rind. The mechanical principles involved in the development of strength or hardness in a structural frame work of this kind are too well known to need a description.

The percentage figures (Table III) are derived from averages for corresponding varieties, and each is based on thirty-six determinations. The comparative degree of lignification, as in other characters tabled above, is expressed as percentage of the total. As the character is developed to a significant extent a considerable time after the development of the joint, it has been worked out and compared only in the basal joint, where it finds its fullest expression.

TABLE III

Relation between the lignification of the inter-vascular parenchymatous cells and the rind-hardness

Variety	Basal joint	
	Lignification of the inter-vascular parenchyma (per cent of the total)	Rind-hardness in lbs.
Co 326	23·5	25·0
Co 285	18·7	20·2
Co 356	17·9	24·4
Co 312	14·5	16·5
Co 213	13·9	18·3
Co 313	11·5	17·0

The order in which the rind-hardness figures appear in Table III is at first sight irregular, but here again a consideration of the two characters already dealt with will show that the exceptions in the list go to prove the rule, for it is easy to see that two important exceptions, Co 356 and Co 213, owe the high values of their hardness, as had been mentioned before, to the predominance in them of character I. Co 313 departs from the expected rind-hardness value to a slight extent as it is partial to the lignification of the vascular sheath, which is its predominating character (Table II and Plate I, fig. 3) and possibly also to some other subsidiary characters such as sub-epidermal cell-wall thickening, etc. Thus when the 'exceptions' are properly accounted for, the general agreement between the character and the rind-hardness becomes evident in all cases.

IV. Discussion

Before evolving the resultant effect of the three factors, it is necessary to understand their inter-relationship and to satisfy oneself of the independent operation of each. In a biological system involving the closest co-operation of tissues and functions, it would be unreasonable to expect a totally independent development of the different components contributing to a common ultimate end and, to some extent, the components will undoubtedly influence each other. But as it happens, the components are really more independent in their operation than can be expected, and this fact has been clearly brought out in the three characters under which the varieties have been considered. Each of the tables in the previous section shows close general agreement between the intensity of the character and the rind-hardness, but a deeper significance comes to be attached to the ' exceptions ' which have been pointed out in each case ; for the turns which the varieties take in assuming the role of exceptions in the successive tables is in itself an indication and a natural consequence of the differential predominance of the characters operative in them. In other words, the varieties which come out as exceptions when their weaker character* is being considered, will naturally come out in the normal sequence when their predominating character is tabled out, and the fact that the same variety does not always stand out as an exception shows that different characters predominate in different varieties in contributing to the hardness of the rind.

The relationships of the characters may now be considered.

1. Number of vascular bundles.—Of the characters examined, this appears to be the most independent one and though it shows considerable variation within a variety, it is not subject to variations in the course of the ontogenic development ; in this respect, it differs from developmental characters like lignification, etc. Indeed, although the present data is insufficient to venture an assertion on the point, it would not be unreasonable to class the density of aggregation of vascular bundles as a varietal character, if varieties show significant differences.

The character, however, is really a part of a greater complex, namely, the actual quantity of the vascular strand element in the body of the cane or its rind. Variation in this complex depends upon the variation in its three independent components—the number, the size and the degree of lignification of the vascular bundles. Of these, the first and the third are studied here as major characters, the second does not appear to have as great an effect on the rind-hardness as the other components, though its variations bear materially upon the vascular density. In the ' dry-leaf ' joint, its variation among the varieties is poor ; in basal joints, its effect is easily masked by lignifications,

*By a ' weaker ' character is here meant the character which does not contribute mainly or largely to the hardness of the rind in that variety, and by a ' predominating ' character is meant the character which does so.

and when varieties (Cos 312, 313, and 213 in Table IV, basal joint), where lignification does not predominate are considered the variation ascribable to the size of the bundle is found to be very poor, so that the character as a whole seems to be far less effective than the other two components.

TABLE IV

Relation between the size of the vascular bundle and the rind-hardness

'Dry-leaf' joint				Basal joint			
Variety	Average area of vascular bundles in 1 sq. mm. of rind in cross-section in sq. mm.	Average area of each vascular bundle in sq. mm.	Rind-hardness ascribable to one vascular bundle per sq. mm. of rind in cross-section in lbs.	Variety	Average area of vascular bundles in 1 sq. mm. of rind in cross-section in sq. mm.	Average area of each vascular bundle in sq. mm.	Rind-hardness ascribable to one vascular bundle per sq. mm. of rind in cross-section in lbs.
Co 326	0·306	0·059	3·231	Co 326*	0·382	0·090	5·859
Co 313	0·317	0·052	2·233	Co 312	0·421	0·080	3·133
Co 312	0·308	0·051	1·714	Co 285*	0·432	0·081	3·789
Co 285	0·346	0·048	1·806	Co 213	0·382	3·064	3·050
Co 213	0·304	0·047	1·809	Co 313	0·355	0·063	3·000
Co 356	0·369	0·042	2·095	Co 356*	0·372	0·055	3·588

*Varieties with highly lignified tissues in the rind.

2. *Lignification of the vascular sheath and of the inter-vascular parenchyma.*— These two characters are related to one another in the sense that they are the manifestations of the same developmental phase. The relationship is also noticeable in the varieties, for, as a rule, the lignification in these proceeds proportionately, though not simultaneously, and varieties showing a high development of the one also show a corresponding development of the other. This, however, is true only as a general rule, for these very characters afford a striking illustration of the partiality shown by varieties (Table V) to any one of the two related characters or to any part of a general character.

TABLE V

Relation between the lignification in the vascular sheath and in the inter-vascular parenchyma

Variety	Lignification in vascular seath (per cent of total)	Lignification of inter-vascular parenchyma (per cent of total)
Co 326	23·1	23·5
Co 285	19·1	18·9
Co 313	16·1	11·5
Co 312	14·4	14·5
Co 213	13·7	13·9
Co 356	13·5	17·9

It will be noticed that while there is in general a relationship between the two characters, two varieties, Co 313 and Co 356 (compare figs. 3 and 2 in Plate I), show a strongly partial development, the former for the lignification of the vascular sheath and the latter for that of the inter-vascular parenchyma. This occasional partiality of certain varieties which can show a perceptible predominance to a part of a general character, makes it necessary to consider these two characters independently.

3. Number of vascular bundles and the lignifications of the inter-vascular parenchyma.—These two by nature of their case, as well as by experimental evidence, have very little inter-relationship. The increase in the number of vascular bundles is generally associated with a reduction in the size of the bundle, so that the possibility of the parenchyma being unduly influenced is obviated.

4. Combined effect.—The characters have been examined in the light of the contribution of each individual character, but in combining them for their resultant effect, one is at a loss to ascribe any proportion for their respective representation. The inequalities due to the characters being expressed in different units are eliminated by reducing the contributory values in each variety to a percentage of the total for all the varieties, thus establishing them on a basis of numerical equality in range. But any assumption on the specific contributory value of each character as a whole can only be based on a theoretical reasoning as no experimental evidence can be obtained on it, and any judgment on the point will naturally be arbitrary.

The first character, the number of vascular bundles per unit area in a cross-section is an independent character; it is in a sense an expression of the quality of the rind as a whole, and not, as in other cases, a quality of particular parts of the rind. In forming a combination with this character, therefore, the other two characters cannot be taken on an equal basis of representation, as they are applicable to only certain parts of the rind-structure. There are two ways in which the other characters may be represented. In the first, one may consider the lignification of the inter-vascular parenchyma as a universal development in all the tissues of the rind, and that of the vascular sheath as an additional and earlier development which is restricted to particular areas. Under this assumption, the average area of the vascular tissues being about two fifths of the total area of the rind in cross-section (Table VI), one may represent the character, *viz.*, the lignification of the vascular sheath at 40 per cent of its value, and the other two characters at their full value.

TABLE VI

Average area occupied by vascular bundles in a cross-section of the rind of the basal joints

Variety	Average percentage area of vascular bundles in a cross-section of the rind
Co 285	43·2
Co 312	42·1
Co 326	38·3
Co 213	38·2
Co 356	37·2
Co 313	35·5
Average percentage area in all varieties	39·1

In the alternative, one may consider these lignification-characters as affecting different portions of the rind, and represent them in the proportion of the areas in which they are effective, 40 per cent in the case of one and 60 per cent in the case of the other. The combined effect has accordingly been calculated on these two bases, and the percentage values (Table VII) obtained from this are compared with the rind-hardness.

TABLE VII

Relation between the combined effect of the anatomical characters and the hardness of the rind

Variety	Combination of characters*		Rind-hardness	
	$A+\frac{2B}{5}+C$	$A+\frac{2B+3C}{5}$	Actual in lbs.	Percentage of total
Co 326	19·3	18·4	25·0	20·6
Co 356	18·5	18·6	24·4	20·1
Co 285	17·2	16·9	20·2	16·6
Co 213	15·4	15·7	18·3	15·1
Co 313.	14·6	15·2	17·0	14·0
Co 312	15·0	15·1	16·5	13·6

*A : The number of vascular bundles per unit area of the rind in cross-section.

B : The degree of lignification of the cell-walls of the vascular sheath in the rind.

C : The degree of lignification of the cell-walls of the inter-vascular parenchyma in the rind.

All the figures in the 2nd, 3rd and 5th columns are expressed as percentages of the total of all the varieties. The rind has throughout been taken at a thickness of 1 mm.

The agreement of either of the calculated combinations with the rind-hardness is very close in the above table and also in the graphical representations (Figs. 1 and 2), indicating that the three major characters studied here account for by far the greatest part of the hardness of the rind in the six varieties taken up. It cannot of course be claimed that these are solely responsible for the hardness, for there are many subsidiary characters apart from the environmental influences which, though not actually concerned in this function, may yet have some influence on the hardening of the rind, or the softening of it. In addition to these subsidiary characters, there may be other internal influences, such as the moisture-content of the cane, the extent of pith and cavity development in extreme cases, and possibly also the morphological characters such as the girth and the shape of the joint. But comparatively, their effect seems to be much less than that of the major anatomical characters.

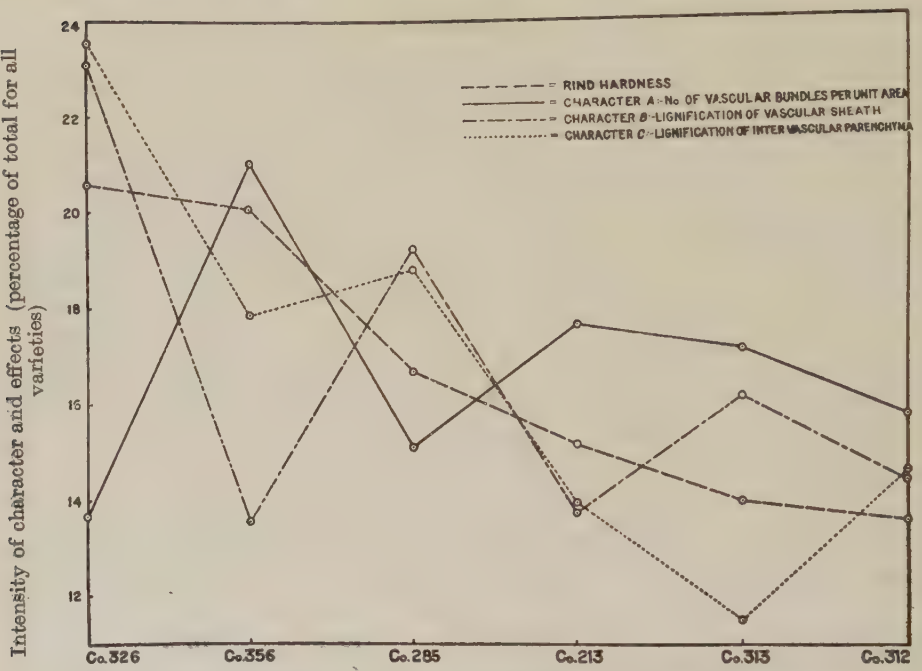


FIG. 1. Anatomical characters and rind-hardness of sugarcane varieties (individual effect)

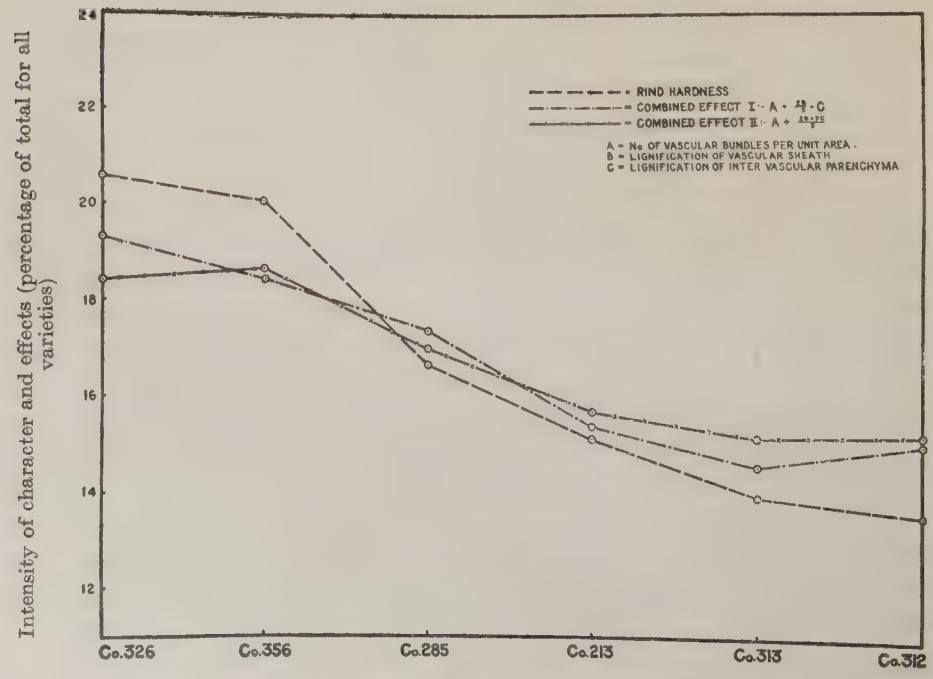


FIG. 2. Anatomical characters and rind-hardness of sugarcane varieties (combined effect)

5. Rind-characteristics in the varieties.—It has been seen that varieties differ from each other in the differential predominance of characters in them and this fact has given some insight into the characteristics of the rind of the varieties. The study having been on small samples, it would not be possible to give a generalized account of these characteristics, but the outstanding features may be examined.

A variety which does not show any outstandingly predominant character is Co 313. It does not even show a clearly marked rind, the vascular bundles being distributed somewhat uniformly. Lignification is poor in the parenchyma, but the vascular sheaths are well lignified (Plate I, fig. 3). The variety shows some resemblance to the softer types of cane.

Co 312 resembles Co 313 in the absence of a sharply-marked rind. The lignification is fair and maintained well into the interior.

Co 213 has a sharply marked rind, the size of the bundles is small, which seems to be a desirable character but the distribution is not as close as in Co 356.

Co 285 is a lignifying cane, both the vascular bundles and the inter-vascular parenchyma lignifying to a high degree. This is reflected in the high value it shows in fibre determinations.

Co 326 and Co 356 are perhaps the most interesting varieties of the series, presenting as they do diametrically opposed tendencies. Co 326 has few and large bundles, but its inter-vascular parenchyma is strongly lignified, the lignification extending so far into the interior as to obliterate the demarcation of the rind and to cause a high fibre-content (Plate I, fig. 4). Co 356, on the other hand, is characterised by an unusually large number of small bundles, well aggregated towards the periphery and cemented together by a sufficiently high lignification of the parenchyma, thereby presenting a comparatively thin but well-marked rind (Plate I, figs. 2 & 5). It has developed the rind-features on what may be called economic lines, and this is well brought out by the fact that though it has a hard rind, its fibre value is comparatively low. Altogether, Co 356 is nearest to an ideal type of cane, as far as the characters in question are concerned, but the fact that it is an intergeneric hybrid between sorghum and sugarcane is not without a significance in this connection.

V. Summary

In an anatomical study on the hardness of the rind in sugarcane varieties, three factors—the number of vascular bundles per unit volume of the rind, the lignification of the cell-walls of the vascular sheaths and the lignification of the inter-vascular parenchyma—were found to contribute in the greatest measure to the hardness of the rind. The degree of development of these characters was found to differ among the varieties, one or the other of the characters

predominating in each of the varieties in contributing to the hardness. Their combined effect, calculated on reasonable proportions of representation for each of the characters, was found to agree closely with the resultant hardness, as determined by the rind-hardness machine.

A few outstanding anatomical characteristics of the rind in different varieties are given, and the features of a desirable type of rind anatomy are demonstrated in one of the varieties.

VI. Acknowledgment

The authors are grateful to the Imperial Council of Agricultural Research under whose scheme for Sugarcane Research in the province the work has been carried out.

REFERENCES

Khanna, K. L. (1934). *Dept. Agric. B. & O. Bull.* No. **6**, 31

———————— (1935). *Agric. & Livestock in Ind.* **5**, 156-158

A STATISTICAL STUDY OF THE LOSS CAUSED BY BORERS AND TERMITES TO MATURE SUGARCANE AT PUSA IN 1935 AND 1936

BY

HEM SINGH PRUTHI, M.Sc., Ph.D. (Cantab.), F.N.I.

Imperial Entomologist

AND

E. S. NARAYANAN, M.A.

Assistant to the Imperial Entomologist, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 18th April 1938)

(With one text-figure)

Introductory

For the last ten years or so observations on the incidence of borers, termites and other pests of sugarcane have been taken at Pusa and some other entomological stations in India. As most of the workers have studied only the extent of the incidence of the pests, the impression prevails that this study gives a full idea of the amount of damage caused by them to the crop. A little consideration will make it clear that if a crop shows an incidence of stem borer of say 12 per cent, it does not necessarily mean that the crop would suffer an actual loss of 12 per cent in weight or sucrose content. Moreover, if a crop is infested by the stem-borer it may not suffer the same amount of loss as the one infested to the same extent by the top-borer, inasmuch as the two pests are quite distinct from each other in their biology and method of attack. Obviously the real criterion of the loss is the decrease in weight of the infested canes and the deterioration in the sucrose content of their juice. The published records * show that while some observations on the weight and sucrose content of canes infested by termites and borers (stem-,top- and root-borer considered together) have been taken on small number of canes at several places in India, hardly any critical study, based on statistical analyses, of the actual loss caused by various pests in the weight and quality of juice of the infested cane has been made in this country. Recently Haldane [1937] has examined a large number of canes from this point of view but his work also is not based on statistical analyses and furthermore he did not differentiate the various borers from one another. We therefore do not yet know the extent of loss caused by different borers individually. The importance of such a study to entomologists as well as to students of agriculture need hardly

* Annual Reports of the Imperial Entomologist for 1931—36, of the Director of Agriculture, Punjab for 1932—36, of the Director of Agriculture, U. P., for 1935-36.

be emphasized. At Pusa in March 1935, a large amount of data, which could be examined statistically, were collected on the variety Co 331, in reference to the loss in weight caused by various pests individually and in combination with one another. The juice of a number of infested canes was analysed to determine the extent of deterioration caused by different pests. In March 1936, five varieties of cane, *viz.*, Cos 331, 313, 299, 231, 213, which had been grown in randomized blocks, were similarly examined. The results of studies made at the two harvests are summarized in the following pages.

The following are the most common species of pests met with :—

Top-borer—*Scirpophaga nivella* Fab. A few specimens of *Scirpophaga monostigma* Zell. were sometimes obtained.

Stem-borer—*Diatraea* (=*Argyria*) *sticticraspis* Hmp., about 85 per cent ; *Diatraea venosata* Wlk., about 12 per cent ; and *Chilo zonellus* Swinh. and others about 3 per cent.

Root-borer—*Emmalocera depressella* Swinh.

Termites—*Odontotermes assumthi* Holmgr.

Material and methods

The crop of Co 331 studied in March 1935 (harvest time) was about one acre in size and was growing in the Gonhri field of the Pusa Estate. The soil of the field was heavy and clayey and the crop was good on the whole. A set of eight plots, each measuring 121 ft. × 6 ft. and having two rows of canes, was selected at random. All canes in the selected plots were uprooted, the pests infesting them, if any, were examined and the canes were sorted out on the basis of infection by different pests. The number of canes in each set and their weight were noted down. The detailed data are given in Appendix I. Again, in the Spring of 1936 similar observations were taken on five varieties, which had been specially planted for the purpose. The soil in this field was clayey and fairly heavy. The field (2·5 acres) was divided into eight blocks and each block was sub-divided into five plots, each measuring 80 ft. × 24 ft., with a six feet passage all round. Each plot contained one particular variety and the planting was done in such a way that each block contained all the five varieties, labelled A, B, C, D, E (Fig. 1). Planting was done in all plots lengthwise (east to west) in rows, three feet apart from one another. Thus there were eight rows of each variety in a plot and the various varieties were distributed at random in each block. At the time of harvest two rows, excluding the border rows, were selected at random from each plot and all the canes therein were uprooted and sorted out in accordance with the pests infesting them and their weight noted. As far as possible the canes were cut and topped at a uniform level. The detailed data are presented in Appendix II, A-E. The percentage number of canes attacked by different borers individually or in combinations, the percentage loss in weights of canes infested by various borers as compared with that of canes free from pests and the total loss sustained in the whole plot due to the attack of pests individually and considered together were worked out for each plot, and on the basis

of these figures the mean and the standard errors were calculated for different varieties separately. It may be noted that the total loss in the weight of cane in each plot due to pests was calculated on the assumption that all the canes in a plot would have the same weight as those which were free from the pest attack. The data for 1936 were analysed according to Fisher's method of analysis of variance. In some replications certain combinations of pests were not met with. The loss of weight in such cases being indeterminate, the standard errors were calculated without eliminating the block effects. The method adopted was the same as the analysis of variance which is used when dealing with samples of different sizes for examining the significance between different means.

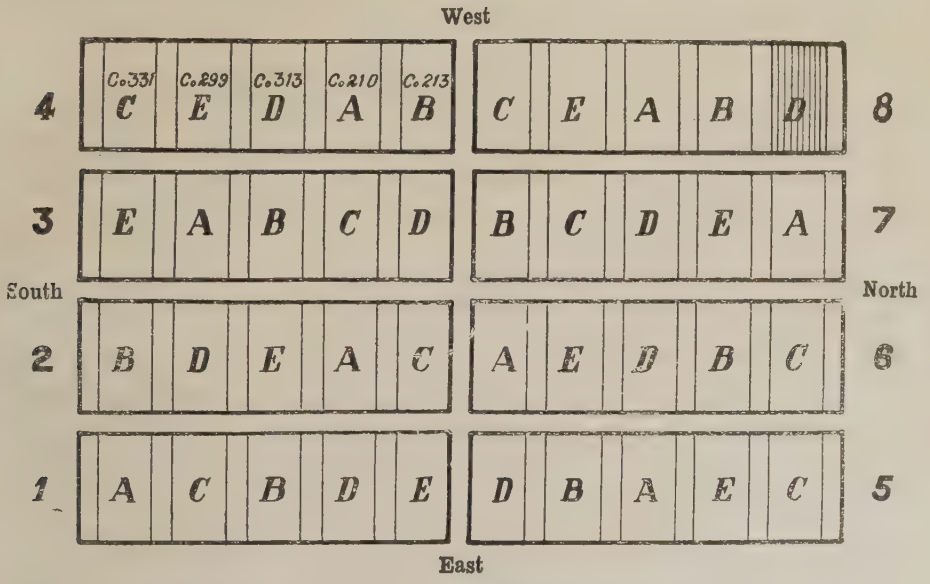


Fig. 1. Lay-out of the experimental blocks in 1935-36

Results and discussion

A. Extent of incidence of various pests

The percentages (means of eight replications) of attacked canes of different varieties per unit area by different pests individually and in combination with one another in 1935 and 1936 are given in Table I (column 2) and Table II respectively. In 1935, $22{\cdot}47 \pm 0{\cdot}89$ per cent of canes of Co 331 were entirely free from pests. Of the various borers, top-borer was found infesting the largest number of canes ($20{\cdot}07 \pm 1{\cdot}14$), root-borer came next ($12{\cdot}39 \pm 0{\cdot}48$), and stem-borer was found in $7{\cdot}90 \pm 0{\cdot}50$ per cent canes only. The attacks of all the three borers were significant. Of the various combinations of borers, top- and root-borers were found in the largest number of canes ($28{\cdot}70 \pm 0{\cdot}89$ per cent). The number of canes attacked by termites alone or in combination with different borers was very small, therefore no reliable conclusions about the extent of incidence of this pest could be drawn.

TABLE I

Percentage of infested canes of Co 331 and percentage loss in their weight due to various pests at harvest in 1935

Pests	Percentage infestation	Percentage loss in weight	Remarks
1	2	3	4
Free from pests . .	22·47±0·89	..	
Root-borer . .	12·39±0·48	—23·63±2·54	Attack significant. Increase in weight significant.
Stem-borer . .	7·90±0·50	+31·96±3·05	Attack significant. Loss in weight significant.
Top-borer . . .	20·07±1·14	5·38±3·20	Attack significant. Loss not significant.
Root- and stem-borers .	1·47±0·26	—12·90±6·66	Attack significant. Change in weight not significant.
Root- and top-borers .	28·70±0·89	13·46±2·87	Attack significant. Loss in weight significant.
Stem- and top-borers .	2·29±0·37	24·91±4·03	Attack significant. Loss in weight significant.
Root-, stem- and top-borers	3·63±0·42	17·20±2·48	Attack significant. Loss in weight significant.
Termites . . .	0·27±0·08	—1·02±13·62	Number of canes attacked by termites alone or by termites in combination with other pests too small to lead to any reliable conclusions.
Termites and root-borer	0·15±0·06	—13·48±4·43	
Termites and stem-borer	..	..	
Termites and top-borer	0·38±0·08	36·51±4·05	
Termites, root- and stem-borers	0·01±0·01	—4·44±..	
Termites, root- and top-borers	0·20±0·13	27·67±3·13	
Termites, stem- and top-borers	0·07±0·05	47·31±5·63	
Termites, root-, stem- and top-borers	..		

TABLE II

Percentage of canes attacked by different pests in 1936

Variety / Pests	Co 331	Co 299	Co 313	Co 213	Co 210	S. E. of mean	S. E. of mean difference	Conclusions as based on analysis of variance
Free from insect pests .	40·53	40·65	18·57	31·42	22·37	2·04	2·89	Varietal differences significant.
Root-borer only. . .	16·92	13·66	13·76	9·89	11·12	1·10	1·55	Amount of attack significant, varietal differences also significant.
Stem-borer only . .	9·40	5·78	13·21	13·96	8·43	1·22	1·73	Amount of attack significant, varietal differences also significant.
Top-borer only . . .	13·92	23·07	13·16	15·43	23·81	1·34	1·90	Amount of attack significant, varietal differences also significant.
Root- and stem-borers .	4·74	1·94	11·18	5·43	3·50	0·52	0·73	Amount of attack significant, varietal differences also significant.
Root- and top-borers . .	7·78	8·89	10·86	6·25	13·73	1·42	2·02	Amount of attack significant, varietal differences also significant.
Stem- and top-borers .	2·79	3·69	7·06	7·70	6·10	0·85	1·20	Amount of attack significant, varietal differences also significant.
Root-, stem- and top-borers	1·29	1·58	8·65	4·38	3·64	1·03	1·45	Varietal differences significant; attack on Co 331 and Co 299 not significant.
Termites only . . .	0·94	0·26	0·46	0·59	1·19	0·32	0·45	Varietal differences not significant, attack on Co 299, Co 313 and Co 213 not significant.

TABLE II—*contd.*

Pests \ Variety	Co 331	Co 299	Co 313	Co 213	Co 210	S. E. of mean	S. E. of mean difference	Conclusions as based on analysis of variance
Termite and root-borer .	1·10	0·11	1·03	1·65	1·37	0·24	0·33	Varietal differences significant, attack on Co 299 not significant.
Termite and stem-borer .	0·31	0·04	0·56	0·52	0·59	0·19	0·26	Varietal differences not significant, attack on Co 331 and Co 299 not significant.
Termite and top-borer .	0·10	0·08	0·23	0·32	1·01	0·15	0·21	Attack significant in the case of Co 210 and Co 213 only.
Termite, stem- and top-borers	0·10	0·04	0·23	0·24	0·31	0·12	0·17	Attack significant in Co 210 only.
Termite, root- and top-borers	0·10	0·08	0·23	1·05	1·51	0·27	0·39	Attack significant in Co 213 and Co 210 only.
Termite, root- and stem-borers	..	0·10	0·46	0·72	0·35	0·14	0·19	Varietal differences significant; attack significant in Co 313, Co 213 and Co 210.
Termite, root-, stem- and top-borers	..	0·04	0·38	0·46	0·95	0·17	0·24	Varietal differences significant; attack significant in Co 313, Co 213 and Co 210.

In 1936 (Table II), Co 299 and Co 331 had the highest percentage (about 40) of canes entirely free from pests, Co 313 and Co 210 had the lowest (18·57 and 22·37 per cent, and Co 213 had 31·42 per cent). The varietal differences in this respect were significant. The percentage infestation of top-borer was highest in almost all varieties (13—24 per cent), root-borer came next (10—17 per cent), and stem-borer infested the least number (6—14 per cent) of canes, except in the case of Co 213, in which it attacked more than the root-borer. In Co 313 the three borers were almost equally common. The attacks of the three borers, individually or in combination with one another, were significant in all the varieties except of the combination top + stem + root borers in the case of Co 299 and Co 331. The varietal differences in the attacks of all borers, individually or in combination, were significant.

Regarding the attack of termites alone or in combination with various borers, it was significant generally in the case of Co 210 only. In most cases the varietal differences were insignificant. In fact termites alone or in combination were present in very few cases and therefore no reliable conclusions could be drawn about the extent of their incidence, as was the case in 1935.

B. Comparative loss in weight of cane due to the attack of various pests

The percentages (means of eight replications) of loss in weight of canes of various varieties due to different pests in 1935 and 1936 are stated in Tables I (column 3) and III respectively.

In 1935 when only Co 331 was examined, the loss caused by stem-borer was the heaviest ($31·96 \pm 3·05$ per cent), *i.e.*, if a known number of healthy canes weighed 100 lbs., those infested by this borer weighed about 68 lbs. only. The loss due to top-borer was not significant. Regarding root-borer, it is noteworthy that the weight of canes infested by this borer was higher by $23·63 \pm 1·54$ per cent as compared with that of canes entirely free from any pest. As will be described hereafter, there was also an increase in the sucrose content of the canes attacked by this borer. The losses due to the attack of the three borers in various combinations with one another were significant except in the case of root + stem borer combination.

In the case of termites, alone or in combination with various borers, the loss was insignificant throughout.

In 1936 (Table III), the loss in weight due to top-borer separately or in combination with other borers was the heaviest and significant in all varieties except Co 299. In the varieties in which the loss was significant, it varied between about 16 and 27 per cent. The varietal differences were significant. The loss due to the attack of stem-borer was not significant in any variety, not even in Co 331, in which as stated above this borer caused the heaviest loss in 1935. The loss due to root-borer was significant in the case of Co 210 and Co 313 only. This year, unlike that in 1935, neither the canes of Co 331 nor of any other variety infested by this borer weighed heavier than the healthy canes. The losses on account of the three borers in combination with one another were significant in the case of all varieties except Co 299, but the varietal differences on the whole were not significant.

TABLE III

Percentage of loss in the weight of canes due to different pests in 1936

Variety / Pests	Co 210	Co 213	Co 299	Co 313	Co 331	Conclusions
Root-borer . .	10·18±4·34	5·46±4·34	8·67±4·34	12·86±4·34	3·01±4·34	Differences between varieties not significant, loss in Co 210 and Co 313 significant.
Stem- borer . .	6·14±4·96	—7·54±4·96	—1·81±4·96	5·80±4·96	6·67±4·96	Loss not significant.
Top-borer . .	18·39±3·09	16·65±3·09	3·26±3·09	16·38±3·09	21·76±3·09	Differences between varieties are significant, loss in Co 210, 213, 313 and Co 331 is significant.
Root- and stem-borers	10·15±1·89	4·51±1·89	0·84±1·89	9·52±1·89	10·63±1·89	Differences between varieties not significant, loss in all varieties except Co 299 significant.

Root- and top-borers	20·65±2·78	22·11±2·78	17·96±2·78	22·32±2·78	26·73±2·78	Differences between varieties not significant but loss significant in all the varieties.
Stem- and top-borers	16·61±4·98	18·74±4·98	3·42±4·98	14·63±4·98	27·02±4·98	Differences between varieties significant at 5 per cent level, loss significant in all varieties except Co 299.
Root-, stem- and top-borers	21·69±6·29	26·12±6·29	5·70±6·29	21·90±6·29	19·62±6·29	Differences between varieties not significant, loss is significant in all cases except Co 299.
Termites . .	10·10±11·26	4·27±11·26	30·45±12·59	5·06±12·59	6·48±10·28	Loss significant in the case of Co 299 only.
Termite and root-borer	16·88±6·30	10·28±6·30	32·97±10·28	9·89±6·73	34·54±6·30	Differences between varieties significant at 5 per cent level, loss in Co 210, Co 299 and Co 331 significant.
Termite and stem-borer	9·55±8·03	28·24±8·03	28·69±16·07	6·84±7·18	13·18±8·03	Differences between varieties not significant, loss in Co 213 significant.

TABLE III—*contd.*

Variety / Pests	Co 210	Co 213	Co 299	Co 313	Co 331	Conclusions
Termite and top-borer	17·66±8·79	14·99±11·63	14·39±16·45	—9·04±10·40	3·16±16·45	Differences between varieties and loss are not significant.
Termite, stem- and top-borers	13·61±14·31	—3·95±20·24	—6·96±28·62	7·17±16·53	7·01±28·62	Differences between varieties and loss are not significant.
Termite, root- and top-borers	27·51±5·45	19·03±5·97	—6·96±13·35	3·21±7·71	—3·33±13·35	Differences between varieties not significant, loss is significant in the case of Co 210 and Co 213.
Termite, root- and stem-borers	4·13±14·17	—4·78±11·57	—7·99±20·04	—2·00±14·17	..	Not significant.
Termite, root-, stem- and top-borers	24·69±8·71	18·67±8·71	60·91±23·05	0·61±11·52	..	Loss in Co 299, Co 210 and Co 213 is significant but differences are not significant.

From the foregoing it will be evident that Co 299 suffered comparatively the least amount of loss in weight due to the attack of various borers separately or in combination with one another.

Regarding termites, when occurring alone they caused significant loss (30·45±12·59 per cent) in the case of Co 299 only. In combination with root-borer they caused significant loss in Co 210, Co 299 and Co 331. When they occurred alone with stem-borer, Co 213 suffered significant loss (28·24± 8·03). Co 210 and Co 213 suffered significant loss when attacked by termites in combination with root and top-borers and with root+top+stem borers. Co 299 also suffered significant loss from the latter combination. But as already stated, the number of canes infested by termites alone or in combination with various borers was very small, therefore no reliable conclusion could be drawn about the loss in weight due to the presence of termites.

In the above paragraphs the comparative percentage losses in weight caused by various pests when occurring alone and in combination with one another have been described. But both from economic and entomological view-points it is also important to ascertain the amount of actual loss caused by various pests individually with known degrees of incidence. For this purpose it is appropriate that only those losses should be compared for which the various borers were responsible when occurring singly, as it is very difficult to assess the amount of loss caused by different borers constituting a combination. The percentages of actual loss in weight caused by different borers, when occurring alone, in various varieties during 1935 and 1936 are given in Table IV. In 1935, when only Co 331 was examined, stem-borer with an infestation of about 8 per cent caused a loss of 2·56 per cent, whereas top-borer with an infestation of over 20 per cent did not cause any significant loss. The weight of canes infested by root-borer was higher by 2·87 per cent. This clearly indicates that the extent of incidence does not give any idea of the loss caused by the pests.

In 1936 when top-borer again infested the largest number of canes of Co 331 as well as of all other varieties under investigation, the loss actually caused by this pest, unlike that in 1935, was heaviest in all varieties. Co 210 suffered the most, having 4·45±0·61 per cent loss, Co 331 came next (3·04± 0·61 per cent), Co 213 showed a loss of 2·49±0·61 per cent, Co 313 had 2·12± 0·61 per cent, whereas Co 299 did not suffer any significant loss.

The stem-borer which infested the least number of canes of all varieties did not cause significant loss to any variety. The behaviour of root-borer was also slightly different from the previous year. Whereas in 1935 the canes of Co 331 infested by this borer weighed more than the healthy canes, in 1936, the canes of this as well as other varieties weighed less but the loss was significant in Co 313 only, being 1·76±0·68 per cent.

TABLE IV

Percentage of actual loss caused by different borers when occurring alone, in the years 1935 and 1936

Year and variety	Top-borer	Stem-borer	Root-borer	Remarks
1935, Co 331	1·02±0·61	2·56±0·33	—2·87±0·24	Loss by stem and gain by root significant.
1936, Co 210	4·45±0·61	0·43±0·47	1·10±0·68	Loss by top alone significant.
1936, Co 213	2·49±0·61	—0·84±0·47	0·59±0·68	Loss by top alone significant.
1936, Co 299	0·67±0·61	0·05±0·47	1·33±0·68	No loss.
1936, Co 313	2·12±0·61	0·87±0·47	1·76±0·68	Loss by top and root significant.
1936, Co 331	3·04±0·61	0·82±0·47	0·19±0·68	Loss by top alone significant.

C. Total loss in weight due to all pests

The total percentage loss in weight of various varieties due to all pests combined was calculated for each plot. The data are summarised in the following statement :—

Year	Varieties					Remarks
	Co 210	Co 213	Co 299	Co 313	Co 331	
1935	..	..	..	..	5·77±1·71	Loss significant
1936	12·81±2·22	9·10±2·22	3·92±2·22	11·62±2·22	7·90±2·22	Loss significant in all varieties except Co 299

From the above it will be observed that whereas in 1935 Co 331 suffered 5·77±1·71 per cent loss, it suffered loss of 7·90±2·22 per cent in 1936. In both years the loss was significant. In the latter year, except Co 299, all other varieties examined suffered significant loss. In the order of loss sustained they could be arranged thus : Co 210> Co 313> Co 213> Co 331> Co 299.

D. Influence of various pests on the cane juice

The chemical analyses of nine samples taken at random of the juice of Co 331 in 1935 and of forty samples of Co 331, Co 313, Co 299, Co 213 and Co 210 in 1936 are given in Tables V and VI respectively.

In 1935 the deterioration in the juice of Co 331 due to the attack of borers was similar to the loss in its weight described above. The stem-borer proved most harmful, as the juice of the canes infested by this borer had 13·07 per cent sucrose content against 16·2 per cent of healthy canes. Those infested by top-borer had 15·50 per cent, whereas those attacked by the root-borer had 17·37 per cent, a little over one per cent more than even the healthy canes. In the case of root-borer the purity of juice was also better, being 89·04 per cent as against 86·77 of the healthy canes. The canes infested by the top and stem-borers in combination had the least sucrose content (10·60 per cent).

TABLE V

Chemical analyses of juice of Co 331 in 1935

No. of sample	Pests	Brix corrected	Percentage sucrose	Percentage glucose	Percentage purity
1	Free from pests . . .	18·67	16·20	0·38	86·77
2	Root-borer . . .	19·51	17·37	0·27	89·04
3	Stem-borer . . .	16·57	13·07	0·61	78·89
4	Top-borer	17·80	15·50	0·42	86·69
5	Top- and root-borers . .	16·67	14·02	0·60	84·24
6	Top-, stem- and root-borers .	15·94	13·06	0·67	81·91
7	Termite and top-borer .	16·77	13·35	1·00	79·78
8	Top- and stem-borers . .	14·00	10·60	0·83	75·70
9	Stem- and root-borers . .	17·21	13·87	0·80	80·56

Table VI

Chemical analyses of juice of Co 210, Co 213, Co 299, Co 313, Co 331 in 1936

No. of sample	Pests	Brix corrected	Percentage sucrose	Percentage glucose	Percentage purity
1	Co 331 Free from pest	18·74	15·52	0·80	82·81
2	,, Root-borer	18·74	15·57	0·93	83·07
3	,, Stem-borer	16·73	13·02	1·17	77·80
4	,, Top-borer	16·96	13·56	1·22	79·97
5	,, Root- and stem-borers	15·93	11·89	1·41	74·60
6	,, Root- and top-borers	12·78	9·11	1·19	71·32
7	,, Stem- and top-borers	13·42	9·59	1·45	71·42
8	,, Root-, stem- and top-borers	13·29	9·44	1·39	71·04
9	Co 213 Free from pest	15·77	12·23	1·28	77·58
10	,, Root-borer	15·13	11·53	1·31	76·21
11	,, Stem-borer	13·88	9·81	1·54	70·70
12	,, Top-borer	13·68	10·17	1·21	72·32
13	,, Root- and stem-borers	15·49	11·77	1·34	75·91
14	,, Root- and top-borers	11·77	7·88	1·59	66·97
15	,, Stem- and top-borers	12·34	8·24	1·59	66·75
16	,, Root-, stem- and top-borers	11·11	6·66	1·64	59·92
17	Co 313 Free from pest	21·11	18·05	0·49	85·51
18	,, Root-borer	22·08	19·00	0·45	86·05
19	,, Stem-borer	20·58	17·42	0·52	85·03
20	,, Top-borer	18·67	15·62	0·69	83·66
21	,, Root- and stem-borers	19·75	16·61	0·69	84·09
22	,, Root- and top-borers	19·85	16·70	0·57	84·12
23	,, Stem- and top-borers	17·13	13·31	1·00	77·70
24	,, Root-, stem- and top-borers	17·30	13·71	0·88	79·42
25	Co 210 Free from pest	18·14	13·40	1·64	73·88
26	,, Root-borer	17·23	12·30	1·74	71·55
27	,, Stem-borer	17·60	12·92	1·64	73·41
28	,, Top-borer	17·74	12·91	1·75	72·79
29	,, Root- and stem-borers	17·68	12·65	1·86	71·54
30	,, Root- and top-borers	16·33	11·11	2·25	68·02
31	,, Stem- and top-borers	16·92	11·67	2·00	68·94
32	,, Root-, stem- and top-borers	15·17	9·7	2·17	63·06
33	Co 299 Free from pest	20·78	17·02	0·99	81·89
34	,, Root-borer	21·28	17·61	1·08	82·76
35	,, Stem-borer	21·15	16·83	1·17	79·58
36	,, Top-borer	20·55	16·55	1·11	80·55
37	,, Root- and stem-borers	20·45	16·42	1·06	80·27
38	,, Root- and top-borers	19·05	14·82	1·39	77·81
39	,, Stem- and top-borers	19·95	15·99	1·20	80·17
40	,, Root-, stem- and top-borers	16·50	12·40	1·56	75·26

In 1936 the damage caused to the juice of Co 331 by the three borers was comparatively of the same order as in the previous year. Canes infested by stem, top and root-borers had 13·02 per cent, 13·56 per cent and 15·57 per cent sucrose content respectively, against 15·52 of the healthy ones. The stem-borer was most harmful, top-borer come next and the canes infested by root-borer had slightly higher sucrose content than even the healthy canes. It will, however, be noticed that the differences between the losses due to various borers were not so large as in 1935. Co 213 suffered due to stem and top-borers in the same way as Co 331, the canes infested by these borers having 9·81 per cent and 10·17 per cent sucrose content against 12·23 per cent of the healthy canes. But no increase in sucrose content was noticed due to root-borer.

In Co 313 and Co 299 top-borer caused more loss in sucrose than stem-borer, whereas in Co 210 the loss was more or less equal. The root-borer behaved in the case of Co 313 and Co 299 in the same manner as it did in Co 331 in 1935 and 1936. In the case of Co 210, as was the case in Co 213 described above, the root-borer decreased the sucrose content like other borers.

Summary and conclusions

A large amount of data on the incidence of various cane-borers and termites and the loss in weight and sucrose content due to the various pests occurring alone or in combination with one another were collected at Pusa at the harvest time (March) of cane in 1935 and 1936. In the former year one variety (Co 331) only was examined, while in 1936 five varieties commonly grown in North Bihar (Co 331, Co 313, Co 299, Co 213 and Co 210), which had been planted in February 1935 in randomised blocks, were under investigation. The results of the observations are briefly summarized below :—

A. Co 331 in 1935

1. About 78 per cent of canes were found infested by one pest or another, $22·47 \pm 0·89$ per cent being healthy (entirely free from pests). Top-borer had infested the highest percentage (about 20 per cent), root-borer was next in abundance (about 12 per cent), and stem-borer was found in the least number of canes (about 8 per cent). The number of canes attacked by termites was too small to lead to any reliable conclusions.

2. Regarding comparative loss of weight due to various pests, if healthy canes weighed 100 lbs., those infested by stem- and top-borers weighed about 68 and 95 lbs. respectively. Thus stem-borer caused the heaviest loss ($31·96 \pm 3·05$ per cent) and the loss due to top-borer ($5·38 \pm 3·20$ per cent) was insignificant. The canes infested by root-borer weighed more than even the healthy canes by about 24 per cent.

3. Regarding the actual loss in weight caused by various borers when occurring alone, with the extent of infestation mentioned in paragraph 1 above, the stem-borer was responsible for $2 \cdot 56 \pm 0 \cdot 33$ per cent and top-borer for $1 \cdot 02 \pm 9 \cdot 61$ per cent (not significant). The canes infested by root-borer showed an increase in weight by $2 \cdot 87 \pm 0 \cdot 24$ per cent.

4. The total loss in weight due to all pests combined was $5 \cdot 77 \pm 1 \cdot 71$ per cent (significant).

5. The canes infested by various pests showed deterioration in the quality of juice in the same order as in the case of weight described above. The stem-borer proved most harmful, the juice of canes attacked by this borer having 13·07 per cent sucrose against 16·2 per cent of the healthy canes. The top-borer-infested canes had 15·50 per cent, whereas the root-borer category had 17·37 per cent, about one per cent more than healthy canes. The purity of canes was also affected in the same order.

B. Co 331, Co 313, Co 299, Co 213, Co 210, in 1936

6. About 60 per cent of canes of Co 331 and Co 299, 70 per cent of Co 213, and 80 per cent of Co 313 and Co 210 were found infested by one pest or the other. The varietal differences were significant. As in the previous year in case of Co 331, top-borer was most common on all the varieties (about 13-24 per cent), root-borer came next (about 10-17 per cent), and stem-borer was the least abundant (about 6-14 per cent). The attack of various borers and varietal differences in this respect were both significant in the case of all varieties. The attack of termites alone or in combination with various borers was significant generally in the case of Co 210 only.

7. Whereas in 1935 the comparative loss in weight of Co 331 due to stem-borer was the heaviest, in 1936 the canes infested by top-borer showed the largest amount of loss in Co 331 as well as in all the other varieties examined, except Co 299, in which the loss was insignificant. The varietal differences were significant. The loss due to stem-borer was not significant in any variety. In Co 210 and Co 313 only loss due to root-borer was significant. In no variety (even Co 331) an increase in weight of cane infested by this borer was noticed, as was the case in Co 331 in 1935.

8. As regards the actual loss caused by the borers when occurring alone, with the extent of infestation summarized in para. 6 above, top-borer caused the heaviest loss in all varieties, varying between 0·67 and 5·45 per cent.

9. The total loss in weight due to all pests combined was significant in all varieties except Co 299. Co 210 suffered the most ($12 \cdot 81 \pm 2 \cdot 22$ per cent), Co 313 came next ($11 \cdot 62 \pm 2 \cdot 22$ per cent), followed by Co 213 ($9 \cdot 10 \pm 2 \cdot 22$ per cent), Co 331 ($7 \cdot 90 \pm 2 \cdot 22$ per cent). Co 299 suffered the least—$3 \cdot 92 \pm 2 \cdot 22$ per cent (not significant).

10. Though the highest loss in weight was observed to be due to top-borer in all varieties and the loss due to stem-borer was not significant in any variety (paras. 7 and 8 above), the highest decrease in sucrose content in the case of Co 331 and Co 213 was observed to be due to the latter borer. In

Co 313 and Co 299, however, top-borer caused more decrease in sucrose content and Co 210 suffered equally from the two borers.

As in the case of Co 331 in 1935, the juice of canes of Co 331, Co 313 and Co 299 infested by root-borer had higher sucrose content than even the healthy canes, though no increase in the weight of canes had been observed (paras. 7 and 8 above).

11. To summarize the results of two years, the top-borer was the commonest borer at Pusa on all the varieties, but the stem-borer seemed to be comparatively more harmful, especially in decreasing the sucrose content of the infested canes. The behaviour of the root-borer was remarkable. In 1935, in spite of its fairly high infestation, the canes of Co 331 attacked by it weighed more and had comparatively higher sucrose content than even the healthy ones. In 1936 though the infestation was almost as high as in the previous year, there was neither increase nor loss in weight. The sucrose content and purity of certain varieties (Co 331, Co 313, Co 299), however, was this year also comparatively slightly higher than that of the healthy canes.

It may therefore be concluded that the extent of infestation did not afford a reliable criterion of the actual loss caused by the pests. For instance in 1935, whereas top-borer was the most common on Co 331, the heaviest actual loss, both in weight and sucrose content, was caused by stem-borer. Further, the actual loss caused by the same pest to various varieties was not in proportion to its degree of incidence. For example Co 210 and Co 299 were found almost equally infested by top-borer in 1936, but whereas the former variety suffered the heaviest loss in weight, there was practically no loss to Co 299. Again Co 331 having less infestation (13·92 per cent) than Co 213 (15·43 per cent) suffered more loss (3·04 per cent) than the latter (2·49 per cent).

As regards the comparative behaviour of the five varieties examined in reference to all the pests considered together, Co 299 proved to be the best variety, as it had the lowest total infestation and suffered no significant loss at all. Co 210 proved to be the worst. The five varieties with regard to the actual total loss in weight sustained by them due to all pests combined could be arranged thus : Co 299< Co 331<Co 213<Co 313<Co 210.

Acknowledgments

We take this opportunity of thanking Mr. P. V. Krishna Ayyar, M.A., Statistician, Imperial Agricultural Research Institute, for the trouble and interest he took in the analysis of our data. He has also gone through the manuscript and made some useful suggestions in reference to statistical interpretations of our observations. To the Imperial Agricultural Chemist we are indebted for the chemical analysis of the juice samples.

REFERENCE

Haldane, J. H. (1937). *Agric. & Live-stock in Ind.* **7**, 599-618

Appendix I

Variety Co 331

Number and weight (in pounds) of canes (eight replications) infested by various pests separately or in combination with one another in 1935

Replications / Combinations	1		2		3		4		5		6		7		8	
	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.
Healthy	178	305·20	211	348	179	308·50	209	400	180	287	189	289·75	165	272·50	174	277·30
Root-borer	89	180·50	97	194·75	116	239·25	124	278	118	248·25	81	169·5	102	212·00	97	182·25
Stem-borer	54	69·25	62	61·25	93	91·25	54	63·25	90	104·13	66	67·50	59	67·80	51	67·18
Top-borer	136	222·63	153	228·8	136	216·5	154	234·25	173	301·75	198	278	198	306·5	179	297·50
Root- and stem-borers	18	38·05	14	21·50	17	31·75	20	34·13	6	11·63	10	21·5	6	12·95	6	9·25
Root- and top-borers	187	256·38	228	308·25	282	404·5	244	355	285	426·25	260	351·25	243	352·95	187	301·88
Stem- and top-borers	26	40·25	15	17·25	26	28·75	11	14	21	27	4	3·95	28	32·50	20	29·50
Root-, stem- and top-borers	24	38·95	22	25·05	46	64·50	23	36	31	40·75	19	24·50	33	42·00	43	63·00
Termites	2	2·25	4	5	5	6·25	1	2·38	2	4	4	8·75	...	...	...	...
Termites and root-borers	...	...	2	3·75	4	7·60	3	6	...	...	...	...	...	...	1	2·0
Termites and stem-borers	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Termites and top-borers	5	5·25	4	5	3	2·50	1	1·25	...	...	3	2·75	3	2·75	5	6·25
Termites, root- and stem-borers	...	...	...	...	1	1·80	...	...	...	...	...	...	...	...	...	...
Termites, root- and top-borers	...	...	1	1·25	9	10·25	4	5·75	...	...	...	...	...	...	...	...
Termites, stem- and top-borers	3	3	...	...	...	...	...	...	...	...	...	...	...	...	1	0·75
Termites, root-, stem- and top-borers	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Appendix II

A. Variety Co 331

Number and weight (in pounds) of canes (eight replications) infested by various pests separately or in combination with one another in 1936

Replications / Combinations	1		2		3		4		5		6		7		8	
	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.
Healthy	86	181	117	299	102	267	87	210·5	111	268·5	100	247	107	218	105	253
Root-borer	44	89·5	23	47	41	89·5	34	76·5	41	77·5	51	148	51	139·5	58	130
Stem-borer	25	59	24	50·5	27	58·5	9	22·5	24	45·5	36	67·5	23	52	21	51
Top-borer	23	38·5	38	60	32	71·5	61	123	40	84·5	23	42·5	27	50	35	53
Root- and stem-borers	10	21	7	16·5	11	26·5	10	20·5	17	35·5	19	37·5	13	27·5	9	16·5
Root- and top-borers	13	21·5	10	17	18	32·5	28	52	9	16	18	27	34	65	29	47
Stem- and top-borers	15	29	7	11	5	10·5	5	9	3	3·5	6	12	7	9·5	7	13·5
Root-, stem- and top-borers	3	7	3	3·5	3	7	4	7·5	3	1·5	4	9·5	6	15	...	...
Termites	3	6	...	...	7	11	...	...	5	10	1	3	2	4	1	2·5
Termites and root-borer	3	4	1	1	4	7·5	5	8·5	2	4	2	3	3	4·5	2	3
Termites and stem-borer	1	1·5	2	5	1	2·5	...	...	2	4	...	...	...	...	...	...
Termites and top-borer	...	...	...	...	1	2·5	...	...	...	...	...	...	1	2	...	...
Termites, root- and stem-borers	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Termites, root- and top-borers	...	...	...	...	...	...	2	5	...	...	...	...	...	...	...	...
Termites, stem- and top-borers	...	...	...	...	...	...	2	4·5	...	...	...	...	...	...	...	...
Termites, root-, stem- and top-borers	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

B. Variety Co 313

Number and weight (in pounds) of canes (eight replications) infested by various pests separately or in combination with one another in 1936

Replications / Combinations	1		2		3		4		5		6		7		8	
	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.
Healthy	52	107·25	54	97	44	87	57	120	27	50·0	39	75·5	61	102	68	128
Root-borer	41	70	37	67	30	48	51	86·5	20	32·25	27	43·5	47	74·5	44	72
Stem-borer	26	50·5	22	45	35	62	25	45	37	66·5	45	82	36	57	54	86
Top-borer	46	86·5	43	67·5	43	64·5	24	40·5	24	38·5	30	46	35	52	36	54
Root- and stem-borers	30	44	25	39	29	52·5	24	41·5	27	57·25	33	53·5	28	52	42	65·5
Root- and top-borers	16	26·5	38	58	29	39·5	50	63·5	17	25·5	20	33·5	32	44·5	31	44·5
Stem- and top-borers	37	59·25	13	27·5	16	28	11	14·5	21	36	13	22	16	23	23	30·5
Root-, stem- and top-borers	16	25·5	22	34	26	38	18	23·5	43	62	15	21	17	29	21	29
Termites	1	1·25	...	...	3	5	...	...	...	...	1	2	5	11	...	...
Termites and root-borer	...	...	6	10	7	9	1	2	1	2·125	2	2·5	3	6	2	3
Termites and stem-borer	...	...	...	...	2	3·5	1	2	...	...	4	9	3	5	2	2·5
Termites and top-borer	...	...	...	...	1	2·5	1	2·5	...	...	1	1·5	1	1·5	1	2·5
Termites, root- and stem-borers	2	3·5	2	5	3	5	...	...	...	...	...	...	3	5	...	...
Termites, root- and top-borers	3	5·0	...	...	...	...	...	...	...	...	1	2	...	...	1	2
Termites, stem- and top-borers	...	...	...	...	...	...	1	1·75	...	...	2	5	...	...	2	2·5
Termites, root-, stem- and top-borers	2	3·5	4	6	1	3	...	...	...	...	1	1·5	...	...	...	...

C. Variety Co 299

Number and weight (in pounds) of canes (eight replications) infested by various pests separately or in combination with one another in 1936

Replications / Combinations	1		2		3		4		5		6		7		8	
	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.
Healthy	128	179·5	94	129	161	210·5	122	158	138	176·5	184	220	152	210·5	159	221·5
Root-borer	40	55	34	50	34	38·5	38	42·5	43	55	64	68	67	67·5	64	81
Stem-borer	28	32·5	14	27	23	30	13	16·5	20	24	17	23	25	32	21	27·5
Top-borer	56	71	96	130·5	96	130	67	82	84	103	81	108·5	89	108·5	73	92
Root- and stem-borers	6	8	12	17	4	5·5	5	7	10	11	3	4	7	8	6	8·5
Root- and top-borers	40	50·5	40	47·5	35	33·5	25	27	35	38·5	8	6·5	30	35	30	35·5
Stem- and top-borers	8	12	13	16·5	17	23·5	18	18·5	14	20	15	14·5	10	13	6	8·5
Root-, stem- and top-borers	3	4	12	16·5	7	9	2	2·5	4	5	3	3·5	4	4·5	9	11
Termites	...	...	1	0·5	...	...	2	3	...	...	...	...	2	1·5	2	2
Termites and root-borer	1	1·25	1	1·0	...	...	...	...	1	0·5	...	...	...	...	...	...
Termites and stem-borer	1	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Termites and top-borer	...	...	...	...	...	...	1	1·75	...	...	...	...	1	0·5	...	...
Termites, root- and stem-borers	...	...	...	...	...	...	...	...	...	...	...	...	1	1·5	2	3
Termites, root- and top-borers	2	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Termites, stem- and top-borers	1	1·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Termites, root-, stem- and top borers		...	...	...	...	...	...	...	1	0·5	...	...	...	...	...	...

D. Variety Co 213

Number and weight (in pounds) of canes (eight replications) infested by various pests separately or in combination with one another in 1936

Combinations \ Replications	1		2		3		4		5		6		7		8	
	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.
Healthy	56	110	100	149	149	270·5	154	238	108	202	114	206·5	108	196·5	87	131
Root-borer	23	37·5	28	43·5	45	73	28	46	29	48	34	62	56	97·5	30	40
Stem-borer	55	100	44	76	28	47·5	86	159	63	112·5	44	75·5	31	78·5	34	56
Top-borer	52	87	55	86·5	46	69·5	59	64·5	42	59	56	82·5	66	98·5	50	63
Root- and stem-borers	19	26	18	31·5	16	24·5	20	31·5	10	20	26	47	23	34·5	19	29
Root- and top-borers	20	30	13	14·5	18	24·5	22	28·5	6	9·5	24	34·5	35	47·5	37	41·5
Stem- and top-borers	48	82·5	22	31·5	14	20	43	62	12	12·5	33	44	11	16	30	38·5
Root-, stem- and top-borers	18	23	20	28	4	6	20	21·5	2	2·5	13	15	12	17	33	35·5
Termites	...	...	3	5	1	1	...	...	7	13	...	...	2	3·5	2	3·5
Termites and root-borer	1	1·8	10	16·5	9	13·5	4	3	5	8	4	8	5	8·5	7	10
Termites and stem-borer	3	4	4	5	3	3	...	...	3	4·5	...	...	...	...	...	...
Termites and top-borer	3	4·5	2	3	...	...	...	...	2	3	1	1·5	...	...	...	...
Termites, root- and stem-borers	...	...	4	7	...	...	1	2·5	2	3	5	8·5	3	4·5	5	7
Termites, root- and top-borers	...	...	1	1·4	6	9·5	...	...	...	...	8	13·5	12	14	3	3
Termites, stem- and top-borers	3	5	3	5·5	...	...	...	...	...	...	...	...	...	...	...	...
Termites, root-, stem- and top-borers	1	1·5	...	...	1	1·25	1	0·75	1	1·5	1	2	6	7·5	2	3·5

E. Variety Co 210

Number and weight (in pounds) of canes (eight replications) infested by various pests separately or in combination with one another in 1936

Replications / Combinations	1		2		3		4		5		6		7		8	
	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.	No.	Weight in lbs.
Healthy	79	126	63	105	55	89	66	125	86	160·5	90	161·5	117	215	58	104
Root-borer	36	47	40	60·5	40	63	46	69	40	78	34	52	34	60	32	48
Stem-borer	45	70	22	35	26	47	18	27	40	70	35	55·5	33	58	10	16
Top-borer	63	88	81	123	77	105	85	117·5	61	86	108	149	80	133	96	127·5
Root- and stem-borers	18	28·5	4	8	10	14	10	15	23	32	6	8·5	15	20·5	10	19
Root- and top-borers	42	56	55	86	47	66	57	77	19	27	32	41·5	26	38	97	124
Stem- and top-borers	20	26	9	17	25	36	25	33	26	41·5	23	24	22	38	18	24·5
Root-, stem- and top-borers	21	26·5	3	5	15	21	17	22	9	12	4	6	23	31	10	11·5
Termites	4	4·5	8	11	8	10	11	23	...	...	...	...	1	2	...	...
Termites and root-borer	5	6·5	3	5	9	10	8	9·5	3	5	2	3·5	7	10·5	1	1·5
Termites and stem-borer	3	5·5	...	...	3	4·5	5	8	5	6·5	...	...	...	...	...	...
Termites and top-borer	4	6	5	8	8	10	3	4	2	3	...	...	1	1·5	4	5·5
Termites, root- and stem-borers	...	...	...	...	2	4·5	...	...	...	...	2	3·5	3	4	3	4
Termites, root- and top-borers	...	...	...	...	5	6	5	8·5	3	4·5	7	8	13	17	10	10
Termites, stem- and top-borers	...	...	3	4	1	2	3	3·5	1	1·5	...	...	...	...	...	...
Termites, root-, stem- and top-borers	2	3	...	...	6	7	3	4	1	1·5	2	3	6	6·5	7	8·5

THE PROTEINS IN THE RICE GRAIN AND THE DEVELOPMENT OF THE ALEURONE LAYER

BY

K. RAMIAH

Offg. Director, Institute of Plant Industry, Indore (Formerly Paddy Specialist, Coimbatore)

AND

C. RAJASEKHARA MUDALIAR

Assistant to Paddy Specialist, Coimbatore

(Received for publication on 28th June 1938)

(With Plates II—IV)

I. Introduction

In connection with the investigation on 'quality in rice' financed by the Imperial Council of Agricultural Research, histological studies of the grain were undertaken at Coimbatore. Some results dealing with the formation of starch, and different colours of the pericarp in the developing grain have already been published [Rajasekhara Mudaliar, 1936 and Ramiah *et al.*, 1937]. The next step in the investigations was (1) to study the nature of the proteins occurring in the aleurone and endosperm cells of the developing grain by micro-chemical methods and (2) to study histologically the differences, if any, in the thickness of the aleurone layer in some typical rices and to determine how far the environmental conditions influence this layer. Since the aleurone layer is known to be the principal seat of rice proteins and since the nutritive value of rice is essentially related to its protein contents besides minerals, the differences in the thickness of the aleurone layer should give a comparative value of the rice quality. The present paper deals with results obtained in these two investigations.

II. Formation of proteins

The existence of aleurone layer in cereals and the large concentration of proteins in it have been recognised by several botanists [Hartig, 1855; Maschke, 1859; Sachs, 1862 and Pfeffer, 1879]; Schenk [1872] [quoted by O'Brein, 1895] found in wheat that Millon's reagent did not affect the aleurone layer, and on this ground he concluded that aleurone was of low nutritive value. He, however, found that the portion of the endosperm adhering to the aleurone was rich in nutritive value. Groom [1893] found that aleurone grains in Gramineae contained double phosphate of calcium and magnesium characteristic of globoids. O'Brein [1895], examining aleurone layers in wheat, stated (1) that there was continuity between the aleurone layer and the endosperm

by protoplasmic network ; (2) that the cells adjacent to the aleurone layer were specially rich in protein matter (gluten) ; (3) that the aleurone layer came into close relationship with the embryo by the continuation of its cells over the external surface of the edge of the scutellum ; (4) that the protoplasm of the embryo was continuous with that of the adjoining aleurone cells and the underlying endosperm and (5) that much oil was present in the aleurone cells and perhaps some carbohydrate also. He suggested that the aleurone functioned as part of the store for the embryo and also helped in conducting food materials.

To study the nature of the proteins occurring in the aleurone and the endosperm cells, micro-chemical studies were undertaken. Very little work has been done hitherto on the micro-chemical study of the proteins in rice grain. Dastur [1935] has made a study of proteins in the rice grain, but the substance orthoquinone, one of the constituents recommended for his reagent, could not, however, be obtained anywhere. Considerable attention had therefore to be devoted first to determine the most satisfactory reagent to give the best stain reaction.

Micro-chemical studies

After testing several reagents, Millon's and Adamkiewicz's reagents were found to give best results, and these have been used in the present investigation. With Millon's reagent, proteins were stained red in all parts of the grain, but this reagent did not give a reaction with aleurone grains in materials tested seven days after fertilisation. Adamkiewicz's reagent gave characteristic reddish violet colour to proteins in the aleurone layers in the same material. Hopkin's and Cole's modification of Adamkiewicz's reagent and syrupy phosphoric acid also gave fairly good results but not quite so definite as Adamkiewicz's. Takahashi [1913], working on proteins of rice, found that all four kinds of proteins occurring in rice—albumin, globulin, prolamin and glutelin—gave positive reactions with Millon's, Adamkiewicz's and Biuret reagents. But as has already been observed in regard to histological sections the first two reagents only were found to be satisfactory.

Though rice is supposed to contain a fairly large proportion of glutelin [Allen, 1930], which is insoluble in water and alcohol, the stain reaction could not be obtained in materials fixed in different fixatives and passed through all stages of dehydration, hardening, etc. Therefore fresh specimens only were used throughout, and free-hand sections were taken for observing the stain reactions. The exact position of spikelets on the panicle was first marked on a paper just when the ear-head had emerged from the sheath, and as the flower opened every day, the date of flowering was marked against each individual spikelet. The exact day of anthesis having thus been recorded for each spikelet, it was found easy to collect ovaries of particular age for free-hand sectioning and staining. Formation of protein was observed from the third day after anthesis right up to the maturity of the grain. Ripe grains had to be soaked several hours in water before taking sections.

FIG. 1. Longitudinal section of rice ovule 3 days old, showing the ovary wall and a portion of nucellus. Periphery of nucellus richer in proteins
P—Pericarp ; (ovary wall)
N—Nucellus

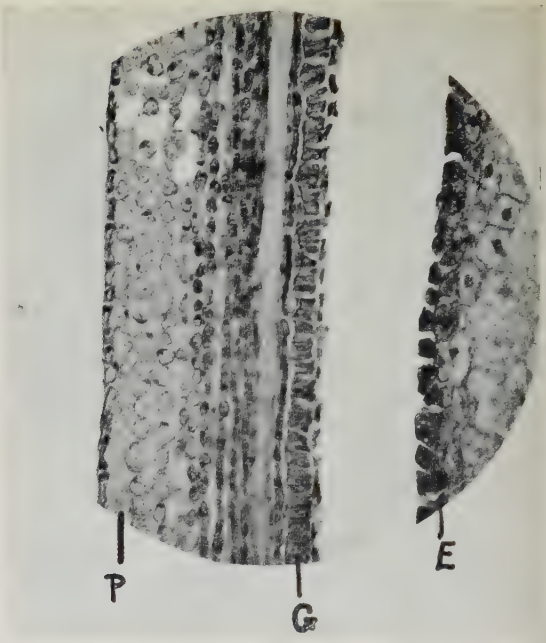


FIG. 2. Longitudinal section of rice grain 5 days old showing ovary wall and a portion of endosperm. Aleurone layers are not yet differentiated. Peripheral cells of the endosperm take deeper stain, suggesting more of proteins
G—Epidermis of nucellus
E—Endosperm

FIG. 3. Longitudinal section of rice grain 7 days old. Aleurone layers are clearly differentiated and are not affected by Millon's reagent but stained by Adamkiewicz's reagent.
A—Aleurone ;

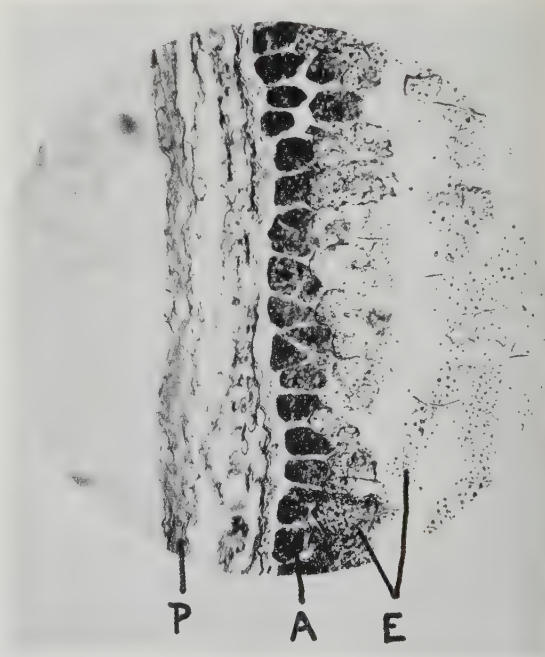


FIG. 4. Longitudinal section of rice grain 30 days old. Pericarp very much reduced. Aleurone layer, A, is very prominent. Stain reaction same as for Fig. 3.

Observations

The following observations were recorded—

Third day after anthesis.—The cells of the ovary wall take a slight reddish colour with Millon's reagent. The conducting strands and the innermost layer of cells of the ovary wall take a deeper stain suggesting larger amounts of proteins. The nucellus was also stained light red but the colour was more towards the periphery than towards the centre of the grain (Plate II, fig. 1).

Fourth and fifth days after anthesis.—With rapid development of the endosperm tissue, the proteins in the ovary wall get gradually exhausted. The outermost layer of cells of the endosperm (aleurone) take a deeper stain than the remaining portion (Plate II, fig. 2).

Sixth day after anthesis.—The aleurone is not clearly differentiated from the endosperm tissue, but the outermost three or four layers take a dark red stain and the colour fades away gradually towards the centre. At this stage the ovary wall contains very little protein.

Seventh day after anthesis.—On the seventh day and thereafter up to the maturity of the grain, the outermost layers of cells of the endosperm were not stained by Millon's reagent while one or two layers adjacent to the aleurone showed an intense colour reaction to the stain. Adamkiewicz's reagent, however, gave the characteristic reddish violet stain in the outermost layers which did not react to Millon's reagent (Plate II, figs. 3 and 4).

Discussion of results

The action of Millon's reagent on the aleurone of rice grains seven days after anthesis corresponds with the observations recorded by Schenk [1872] in wheat, but the action of Adamkiewicz's reagent definitely proves the presence of proteins in the aleurone. It is possible that the occurrence of some other substance in the aleurone after this stage retards the action of Millon's reagent. Lloyd [1926] states that the colour tests for proteins are not due to proteins as such but due to certain groups (amino-acids) commonly occurring in them, that tryptophane is responsible for the colour reaction obtained with Adamkiewicz's reagent, and that tyrosine brings about the colour changes due to Millon's reagent. It is probable that the aleurone layer in materials tested seven days after fertilisation consists mostly of tryptophane, while the few layers of the endosperm adjoining the aleurone consists mainly of tyrosine. Lloyd [1926] states that tryptophane has some individual role to fulfil in metabolism over and above that of supplying a quota of nitrogen to the system. Aykroyd and Hopkins [1916] showed that removal of tryptophane from the diet of young growing rats was immediately followed by a rapid loss of weight, and its restoration produced renewed growth. Tryptophane therefore appears to be an essential constituent of animal diet, and since the aleurone is rich in tryptophane it follows that this layer is the most important nutritive portion of rice. The seat of tyrosine in the rice grain may be the first one or two layers of cells

adjoining the aleurone layer. The evidences of the importance of tyrosine in the diet of animals are conflicting. In the case of rats, its presence was not found to be so very essential [Totani, 1916].

The occurrence of large quantities of proteins in the peripheral layers of the endosperm confirms O'Brein's [1895] observations in wheat and it is no doubt due to the protoplasmic network connecting the aleurone with the endosperm. O'Brein's findings about the protoplasmic connections between the embryo and the surrounding aleurone layer are also borne out in rice. It is observed in rice sections that portions of coleoptile, plumule, coleorhiza, and root tips which are adjacent to the aleurone layer take a deeper stain reaction with Adamkiewicz's reagent than the interior portions. It is clear that the proteins are first concentrated in aleurone layers and later (seven days and more after fertilization) they pass on to the adjacent endosperm cells and those parts of the embryo which are nearer to the aleurone layer. Similar observations have also been reported by Yamasaki [1933] in wheat ; he states that there are one or two layers of starch cells of a special type adjoining the aleurone which have thicker cell walls and are rich in gluten content. Some preliminary observations of market samples of rices have revealed that in all samples examined, the aleurone layers have been removed completely, thereby indicating that tryptophane which is an important principle of diet is not obtainable in highly polished market rices. Even the less important constituent, tyrosine, is absent in several samples.

III. Histological studies

The only reference available regarding the histological study of the aleurone layer in rice grain is that of Iliffe [1929] who measured the thickness of the aleurone layer in some rice varieties at the Paddy Breeding Station, Coimbatore.

Material and method

To measure the thickness of the aleurone layer in different types of rices and in rices grown under different manurial treatments, a special method had to be devised. A few varieties in each of the following groups were studied.

1. White rice varieties of different duration.
2. White and coloured rices.
3. Soft, hard, glutinous and wild rices.
4. Rices from different manurial experiments.

The method of taking specimens of required age and fixing, cutting, staining, etc., are explained by Rajasekhara Mudaliar [1936]. This method is slightly different from the one adopted by Brenchley [1909] for cutting sections of wheat grain. In this method, ovaries of above fifteen days' age were subjected to special treatment. After fixing in formalin-acetic-alcohol the grains were treated with a mixture of one-third glycerine and two-thirds

VARIATIONS IN ALEURONE THICKNESS
IN THE WHITE RICES

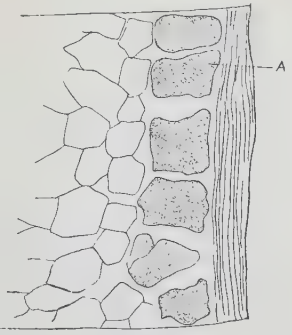


FIG. 1. GEB 24

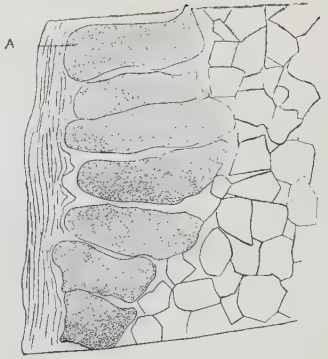


FIG. 2. Co 4

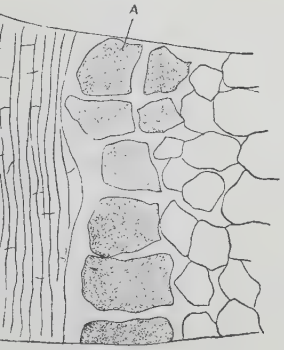


FIG. 3. Co 10

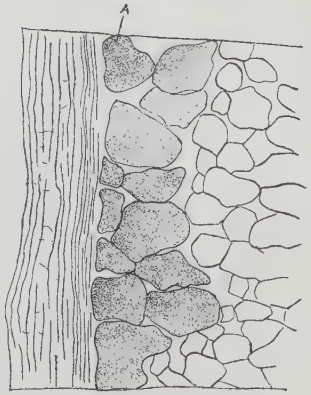


FIG. 4. Co 5

. 1–4. Sections of white rice varieties, drawn to same magnification (×300)

The good development of aleurone in the coarser variety, Co. 4 may be noticed
A—Aleurone

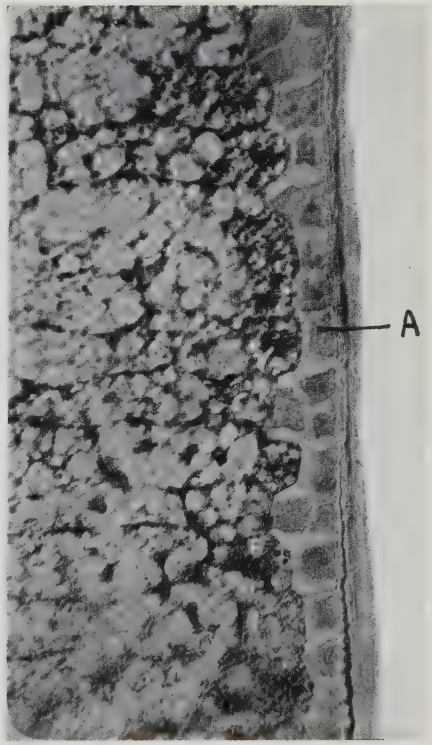


FIG. 5. Longitudinal section of the rice grain obtained with 4,000 lbs. green leaf

A—Aleurone on the dorsal side of the grain

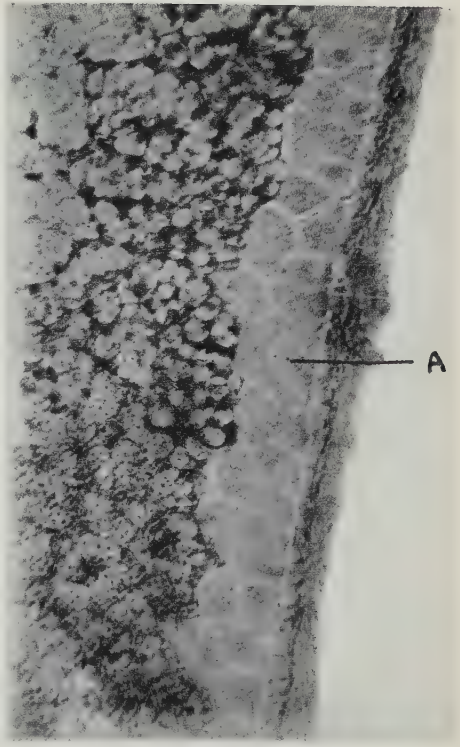


FIG. 6. Longitudinal section of the rice grain obtained by manuring the crop with 20,000 lbs. green leaf per acre. The extraordinary development of the aleurone in the manured seed may be noted

rectified spirit for about a week and then passed on to paraffin infiltration through the medium of Bergamot oil. The embedded material was cut and the cut surface was soaked in water for at least twelve hours before cutting the sections. Longitudinal sections, 10 to 12 μ thick, were then cut and stained in picro-anilin-blue. This stain gave to the aleurone layers a rich blue colour, while the endosperm took a light green stain. The growth and development of the aleurone layer were studied at three different stages of growth, namely, seven, sixteen and thirty days after fertilisation.

Some general observations on the formation and development of aleurone grains may also be recorded. The aleurone grains on the ventral side (the side along the embryo) are generally single layered, while those on the dorsal side (the side opposite to the embryo) are generally two to three celled. Even the individual cells of the aleurone are thicker on the dorsal side than on the ventral. The aleurone layers surrounding the embryo all round are very thin, even thinner than those on the ventral side, and they gradually increase in thickness towards the middle of the grain. This thickness is generally maintained up to the tip of the grain. The aleurone layers below the conducting strands, which traverse the grain on the dorsal side, are the thickest. Just seven days after anthesis, one or two peripheral layers of the endosperm get denser in cell contents, and take a deeper stain with picro-anilin-blue, and these cells ultimately differentiate as the aleurone layers. At this stage vacuolation is faintly seen in the aleurone cells, and it becomes prominent with the ripening of the grain. The cell contents of the aleurone get denser till the sixteenth day, after which they begin to contract and recede towards a side wall, and at the ripening of the grain they appear contracted in most cases. Measurements of aleurone grains were taken from both the dorsal and the ventral side and each measurement consisted of six to ten readings.

White rices of different duration.—Seven varieties were examined under this group of which one was of short duration, two of late duration and four of medium duration (Table I). The most striking difference noted between the short and long duration varieties is that even on the seventh day after anthesis, the aleurone is much better developed and differentiated in the short duration variety than in the long duration one. In the two varieties belonging to the latter group, Adt 11 and Co 4, the formation of the aleurone is not observed till the seventh day, whereas in varieties of medium duration, *e.g.*, GEB 24, Co 1, Co 5 and Co 7 it did appear on that day. As regards the final stages of development there are no apparent differences among different groups. Variation in the aleurone thickness among these rices can be seen from Plate III, figs. 1—4.

White and coloured rices.—During his preliminary studies on the histology of the rice grain, Iliffe [1929] has recorded that there are variations in thickness of the aleurone in differently coloured rices. The aleurone was slightly thicker in red rices than in white ones. A summary of results obtained by him and later published by Ramiah [1936] is given below in a tabular form.

Thickness of bran layers in rice

Variety	Grain size (coarse, fine, etc.)	Thickness of bran layer in microns (Pericarp+Aleurone)		Rice colour
		Dorsal side	Ventral side	
Black puttu	Coarse	62·3	40·5	Purple
T 303	Do.	53·3	37·4	White
T 326	Do.	54·1	32·8	Do.
T 88	Do.	48·8	32·1	Grey brown
T 219	Do.	50·1	30·6	White
Co 4	Do.	48·1	28·5	Do.
T 29	Do.	52·8	39·3	Red
T 248	Do.	44·1	38·3	Do.
T 375	Do.	41·0	31·3	Do.
T 73	Medium	54·8	33·8	Do.
T 132	Do.	56·6	39·1	Brown
Co 6	Do.	43·8	28·8	White
Co 5	Do.	44·5	30·3	Do.
Co 7	Do.	41·8	31·6	Do.
Co 2	Do.	47·8	28·8	Do.
T 218 (Adt 4)	Do.	36·8	21·3	Do.
T 217 (Adt 3)	Do.	36·0	22·0	Do.
Co 3	Do.	34·3	22·0	Do.
Co 1	Medium fine	42·3	25·8	Do.
T 2	Fine	42·6	25·6	Do.
T 124	Do.	47·1	27·3	Do.
T 109	Do.	37·8	24·8	Do.
GEB 24	Do.	35·3	26·1	Do.

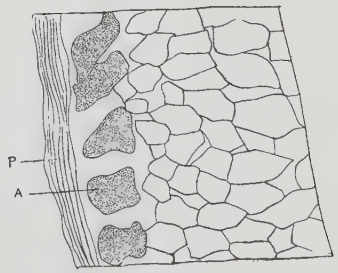


Fig. 1. White

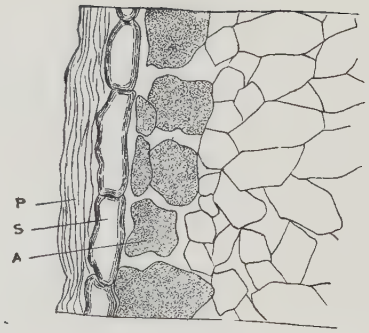


Fig. 2. Red

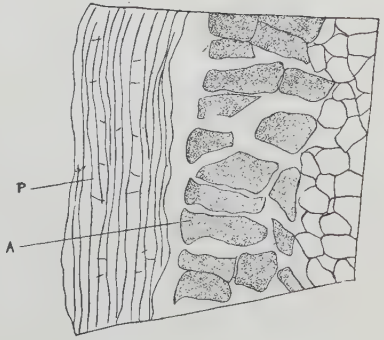


Fig. 3. Dark purple

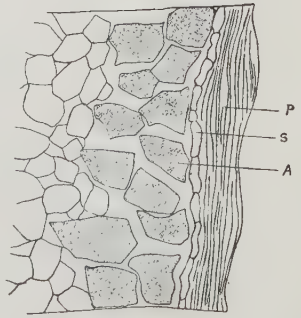


Fig. 4. Brown

Figs. 1–4. Longitudinal sections of different coloured rices (×300) all drawn to same magnification

P—Pericarp

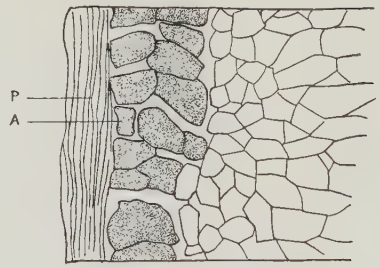


Fig. 5. Cultivated rice

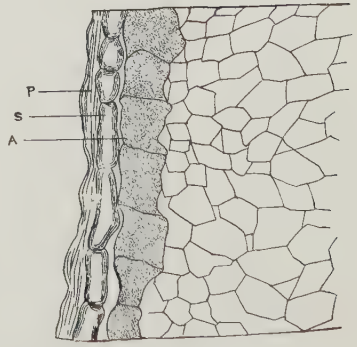


Fig. 6. Wild rice

Figs. 5–6. Longitudinal sections of cultivated and wild rice. The poor development of aleurone in the wild rices may be noticed. (×300)

S—Spermoderm

To confirm these observations further, the thickness of aleurone was measured at three different stages, in eight different varieties, of which three are the same as those mentioned in Table I. The description of these varieties and the measurements are given in Table II. It will be seen that besides colour, the varieties differ in size also, some being definitely coarser than others.

It is generally observed that in coloured rices examined on the seventh day after anthesis, the aleurone can be seen on the dorsal side alone while on the ventral side it is not yet differentiated, the purple rice being an exception. In the grey-brown rice, the aleurone on the ventral side is not distinguishable even on the sixteenth day. In this rice, the aleurone development is poor and even at the ripening time, the cell contents are not concentrated and vacuolated like other varieties.

Glutinous, hard, soft and wild rices.—In this group five varieties—two glutinous (black and white), one non-glutinous but hard and translucent, one non-glutinous but soft and opaque and a wild rice (*O. officinalis*)—were examined (Table III). The glutinous varieties selected for the study show the greatest development of aleurone so far examined. The increase of aleurone thickness in them is more marked during seventh to sixteenth day.

Results.—The results given in Tables I to III may be briefly examined. It may be stated at the outset that in order to get differences in thickness of the aleurone layer between different groups of rices, such as early or late, white or red, coarse or fine, and glutinous or non-glutinous, a much larger number of varieties should have been examined under each group independently. It is only then that the data could lend themselves to a statistical analysis. As it is, the inferences drawn are only indicative. The results in Table I do not show any striking differences except that in an early variety, Co 10, the formation of aleurone is much earlier than in others. The small increase in aleurone thickness in the case of Co 7, Co 4 and Adt 11 might probably be due to their being comparatively coarser grained than others. From Table II, it will be seen that in red rices, T 111 and Co 9, the aleurone is thinner in the finer one (T 111) than in the coarser type, Co 9. This difference is, however, not quite so definite when two white rices, a fine and a coarse (GEB 24 and Co 4), are compared, but then it must be said that Co 4 is not quite so coarse in comparison with GEB 24 as Co 9 is with T 111. Among coloured rices differences do exist as are visible in Plate IV, figs. 1-4. Colour as such does not appear to influence the thickness of the aleurone layer but the indication that coarser rices, whether coloured or white, have thicker layers than finer rices appears to be more definite. Though previous workers [Kikkawa, 1919 and others] have recorded the existence of empty spaces or gaps in the structure of grains indicative of their softness, the soft rices examined have not revealed the presence of such empty spaces. Comparison of a hard (T 167) and a soft (T 523) rice definitely shows that the aleurone is thicker in the former than in the latter (Table III). In regard to wild rice (T 573) the aleurone layer appears thin when compared to cultivated rices (Plate IV, figs. 5 and 6). The micro-photographs clearly show

that the aleurone has not concentrated and receded from the cell wall even at ripening in many of the cultivated rices. As the pericarp colour is red, the colouring layer, spermoderm, is very conspicuous.

Effect of environment on aleurone development.—(*a*) The most important environmental factor that may normally be expected to have the most profound effect on the plant is the manure applied to the soil in which the plant is grown. In a manurial experiment conducted at four centres, *i.e.*, Coimbatore, Maruteru, Berhampur and Pattambi, the same variety of paddy, *i.e.*, GEB 24 was planted, and its grains were examined for aleurone thickness. The following four identical treatments were given at all centres :—

A.—No manure.

B.—Ammonium sulphate to supply 30 lb. nitrogen per acre.

C.—Sodium nitrate to supply 30 lb. nitrogen per acre.

D.—Green leaf to supply 30 lb. nitrogen per acre.

The measurements of aleurone thickness in grains thirty days after anthesis are recorded in Table IV. Measurements were taken only on the dorsal side. The results are definite and interesting. Taking A as control, the effect of treatment D in increasing the aleurone thickness is significant at all four centres. The effects of B and C have been variable in the different centres, but next to D, treatment C has got a significant effect at three centres, Maruteru, Pattambi and Berhampur. The difference between C and D is significant at Maruteru and Coimbatore and there is no difference among treatments A, B and C at Coimbatore.

The application of bulky organic manures, like green leaf, has contributed to the maximum thickness of the aleurone layer and next to green leaf comes the chemical fertiliser in the form of sodium nitrate. Taking aleurone thickness as an indication of grain quality, of the two chemical fertilisers, sodium nitrate and ammonium sulphate, the former contributes more to the quality of the produce while the latter to the quantity.

Apart from the effects of the manure applied, something might be said of the effect of the place also on the development of the aleurone. The Maruteru soils being clay are richest and ideal for paddy cultivation, while those of Pattambi poorest, being shallow laterite. The soils of Coimbatore and Berhampur are intermediate in character. Taking treatments A and D alone into consideration, the thickness of aleurone in A is lowest in Pattambi and highest in Maruteru and the increase in thickness due to treatment is significantly high in Maruteru compared to these treatments at other three centres. It must be stated, however, that the seed grown in three centres other than Coimbatore was not sent from Coimbatore during the year of the experiment but was the produce of a crop grown locally for some years with the seed originally obtained from Coimbatore. It may be suggested that the big difference shown at Maruteru might have been brought about by cumulative effect, since this station has been growing this variety for a number of years.

(*b*) Advantage was taken of another seed-bed manurial experiment in progress at Coimbatore to examine the produce for the thickness of the aleurone layer. The grain examined (Co 1) came from the two treatments mentioned below :—

A.—No manure in both seed-bed and transplant field.

B.—Heavily manured seed-bed (20,000 lb. green leaf+1 cwt. each of ammonium sulphate and super phosphate per acre) and normally manured transplant field (4,000 lb. green leaf+1 cwt. of ammonium sulphate).

The measurements of the grain are recorded in Table V. Unlike the previous experiment, aleurone thickness was measured at three stages of development both on the dorsal and ventral sides. The difference between the treatments at the first two stages is not significant but it is highly significant at the last stage, particularly on the dorsal side. The better development of the aleurone in treatment B is evident from the sections of grains (Plate III, figs. 5 and 6).

Discussion.—Iliffe [1929] suggested that coloured varieties generally have thicker aleurone layers. This has not been brought out definitely in the present investigation though there are some indications to that effect. The examination of a larger number of samples would settle the point. On the other hand, the fact that coarser varieties have thicker aleurone layers than finer ones, irrespective of colour is more definitely brought out. This agrees with the findings of the Bio-Chemist [Anonymous, 1937] in charge of the quality investigations in Bangalore, who as a result of chemical analysis and actual feeding trials with pigeons has stated that " coloured and coarse grained varieties of rice contain larger amounts of proteins and mineral matter than the finer ones ". This should mean that with the same amount of polishing the coloured and coarser rices will lose much less of nutrient matter than the finer ones. These findings support the general opinion prevalent even now in rural parts that coloured and big rices are comparatively more nutritious and labouring classes often state that such rices are more sustaining than the so-called superior finer rices. That glutinous rice is also more nutritious than the non-glutinous is confirmed by these investigations.

McCarrison [1924], as a result of his investigations on the nutritive values of rices in South India, considered that these might vary with soil conditions. Again he found (quoted by Viswanath) that the nutritive value of *ragi* (*Eleusine coracana*) varied with the manurial treatment of the soil. The present investigations of the effect of environmental conditions, such as the nature of soil and manuring, on the quality of rice grains as shown by the aleurone thickness confirm McCarrison's conclusions.

In fact experimental evidence has been produced to confirm the popular opinion commonly expressed that the same variety of rice will vary in nutritive quality according to the place in which it is grown. Regarding the effect of organic and chemical fertilisers on the quality of the crop, Viswanath *et al.* [1926] concluded (*i*) that a crop manured with organic manure (cattle

manure) gave seed with a better cropping value than that from a crop manured with mineral manure or not manured at all ; (*ii*) that mineral manure was better than no manure from the point of view of the quality of the seed. These observations were confirmed by McCarrison who simultaneously carried out nutrition experiments with animals, with the same materials used by Viswanath for his studies. The present investigations have shown that organic manure (green manure) has the greatest effect in increasing the thickness of aleurone, followed by mineral manures, of the type of sodium nitrate, over the no-manure treatment. Nothing can be said, however, of the better cropping value of the produce from the field manured with organic manure. The increase in thickness of the aleurone naturally improves the nutritive quality of the grain, but it does not follow that such an improvement should mean an improvement in the cropping quality. The present investigation is the first recorded instance of manuring or soil conditions having a direct effect on the structure of the grain which is indirectly related to its nutritive value.

Summary of results

(*i*) Millon's and Adamkiewicz's reagents were used to trace the formation of proteins and the latter was found to be more satisfactory.

(*ii*) Small quantities of proteins are observed in the ovary wall up to the fifth or sixth day after anthesis and they get gradually exhausted after the development of the aleurone and starch cells.

(*iii*) The composition of proteins in the aleurone layer probably changes into some other form (seventh day after anthesis). It is quite likely that the aleurone after this stage consists mostly of tryptophane while proteins in other portions of the grain are mainly composed of tyrosine.

(*iv*) One or two layers of cells of the endosperm adjacent to the aleurone are rich in proteins. In the embryo, the concentration of proteins are more towards the portions adjacent to the aleurone layer.

(*v*) The aleurone cells on the ventral side of the grain are generally single layered, while on the dorsal they are two to three celled ; these are thickest just below the conducting strands which traverse the grain on the dorsal side.

(*vi*) There are indications to show that in an early variety the aleurone develops earlier than in the late varieties.

(*vii*) There is a slight indication that coloured rices have thicker aleurone than the white rices, but the aleurone thickness seems to depend to a large extent on the coarseness of the grain. The aleurone development is at its maximum in the purple rice.

(*viii*) Maximum development of aleurone has been observed in the glutinous rices, while the poorest development is recorded in a wild rice.

(*ix*) Manurial experiments with green leaf and chemical fertilisers, like ammonium sulphate and sodium nitrate, conducted at four centres with the same varieties of rice, have shown that green leaf contributes to the greatest

development of the aleurone followed by sodium nitrate, while the thickness of the aleurone is poorest in no-manure plot. Initial soil-fertility differences also contribute to differences in aleurone thickness.

Acknowledgments

The writers wish to express their indebtedness to the Imperial Council of Agricultural Research for financial help given in connection with the investigation on ' Quality in Rice '. They are also indebted to Mr. C. R. Srinivasa Ayyangar, Paddy Specialist, for allowing them to make use of the data collected at Coimbatore since the senior author left for Indore.

REFERENCES

Aykroyd, W. R. and Hopkins, F. G. (1916). *Biochem. J.* **10,** 551

Allen, A. H. (1930) " Commercial Organic Analysis ". (V-edition Vol. 8). J. & A. Churchill, London

Anonymous (1937). " Progress report of the scheme of research on quality in crops with special reference to rice ". Ind. Inst. Sci., Bangalore

Brenchley, W. E. (1909). *Ann. Bot.* **23,** 117

Dastur, R. H. (1935). *Curr. Sci.* **3,** 432

Groom, P. (1893). *Ann. Bot.* **7**

Hartig, T. (1855). *Bot. Treit,* S. **881,** x

Iliffe, R. O. (1929). *Mad. Agric. Stn. Rep.*

Kikkawa, S. (1919). *J. Coll. Agric. Tokyo* **3,** 11

Lloyd, D. J. (1926). " Chemistry of Proteins ". J. & A. Churchill, London

Maschke, O. (1859). *Bot. Ztg.* **17,** 409

McCarrison, R. (1924, 1). *Ind. Med. Res. Mem.* No. **2**

———— (1924, 2). *Brit. Med. J.* **29**

———— (1926). *Ind. J. Med. Res.* **14,** 351.

O'Brein, M. (1895). *Ann. Bot.* **9**

Pfeffer, W. (1872). *Pringsheime Jahrb.* **8**

Rajasekhara Mudaliar, C. (1936). *Proc. Assoc. Econ. Biol. Coimbatore*

Ramiah, K. (1936). *Curr. Sci.* **5,** 215

Ramiah, K. and Rajasekhara Mudaliar, C. (1937). *Ind. J. Agric. Sci.* **7,** 863

Sachs, J. (1862). *Bot. Ztg.*

Schenk, H. (1872). *Untersuchungen, Wien.*

Takahashi, T. (1913). *J. Coll. Agric. Tokyo* **5,** 135

Totani, G. (1916). *Biochem. J.* **10,** 382

Viswanath, B. and Suryanarayana, M. (1926). *Mem. Dept. Agric. Ind. (Chem. Ser.)* **9**

Yamasaki, M. (1933). *J. Agric. Expt. Stn., Japan 2,* **2**

TABLE I

Thickness of aleurone layer in white rice varieties of different duration

Strain number	Ripening duration (days)	Thickness of aleurone layer in microns (mean of six readings)					
		Seventh day		Sixteenth day		Thirtieth day	
		Dorsal side	Ventral side	Dorsal side	Ventral side	Dorsal side	Ventral side
Short duration							
Co 10 . .	125	10·0±0·67	7·9±0·7	33·6±1·2	18·0±0·8	29·4±1·1	26·4±1·2
Medium duration							
Co 1	155	9·8±0·6	6·7±0·5	21·0±1·7	13·8±1·7	30·6±2·0	20·4±0·8
Co 7	157	12·0±0·6	..	36·0±3·2	29·0±2·0	36·0±3·3	28·0±0·9
GEB 24 . . .	149	21·0±1·1	8·1±0·4	28·2±1·9	24·6±1·4	26·1±0·6	21·0±0·6
Co 5	164	11·0±0·6	7·7±0·3	25·8±0·6	20·1±0·6	27·0±0·6	13·2±0·7
Long duration							
Co 4	192	..	..	29·4±1·1	16·8±0·6	34·2±1·2	18·0±0·3
Adt 11 . . .	176	..	..	25·8±2·1	15·4±0·7	30·0±1·2	24·9±1·2

TABLE II

Aleurone thickness in white and coloured rices

Variety	Rice colour	Breadthe of the grain in mm.	Coarse or fine	Aleurone thickness in microns (mean of six readings)					
				Seventh day		Sixteenth day		Thirtieth day	
				Dorsal side	Ventral side	Dorsal side	Ventral side	Dorsal side	Ventral side
GEB 24	White	2·1	Fine	21·0±1·1	8·1±0·4	28·2±1·9	24·6±1·4	26·1±0·6	21·0±0·6
Co 4	Do.	2·4	Coarse	..	..	29·4±1·1	16·8±0·6	34·2±1·2	18·0±0·3
Co 1	Do.	2·3	Medium fine	9·8±0·6	6·7±0·5	21·0±1·7	13·8±1·7	30·6±2·0	20·4±0·8
Co 9	Red	2·7	Coarse	8·3±0·5	..	24·5±2·2	15·5±0·8	30·6±1·2	18·0±·01
T 111	Do.	1·8	Fine	7·5±0·3	..	27·3±2·1	11·6±1·2	20·0±1·4	12·0±1·1
T 149	Gold	2·4	Coarse	11·0±0·7	..	20·2±2·4	32·2±2·2	31·6±1·0	29·2±2·1
T 150	Grey-brown	2·9	Do	11·2±0·4	..	23·7±1·3	..	26·0±0·8	19·3±2·2
T 134	Purple	2·7	Do.	8·6±0·4	8·2±0·4	19·8±1·8	22·2±0·7	33·0±3·5	29·2±1·0

Table III

Thickness of aleurone layer in glutinous, hard, soft and wild rices

Name of variety	Thickness of aleurone layer in microns (mean of six readings)						Difference significant or not
	Seventh day		Sixteenth day		Thirtieth day		
	Dorsal side	Ventral side	Dorsal side	Ventral side	Dorsal side	Ventral side	
			Glutinous				
1. White puttu (T 304)	16·8±0·8	8·8±0·9	47·4±4·0	21·0±3·0	56·0±3·2	26·0±2·4	Between 1 and 2 significant
2. Black puttu (T 102)	20·2±0·8	15·4±0·5	40·2±1·4	23·4±0·8	48·6±0·8	23·4±0·8	
			Hard				
3. Starch (T 167) .	8·2±0·4	6·8±0·1	36·0±1·9	25·2±2·7	33·3±2·3	25·2±2·1	Between 3 and 4 significant
			Soft				
4. Starch (T 523) .	16·5±0·8	9·5±0·7	28·9±1·2	18·0±0·9	20·7±1·8	19·3±1·4	
			Wild				
5. Starch (T 573) .	9·8±0·7	7·6±0·7	19·0±0·9	9·7±0·6	23·0±2·3	16·0±1·8	Between 3 and 5 significant

Table IV

Aleurone thickness of GEB 24 crop raised under different manurial treatments at different places

Place	Manurial treatments	Thickness of aleurone in microns (30 days old) (Mean of 6 readings)	Difference significant or not
Coimbatore	A	17·1±0·6	
	B	19·8±2·0	Over A not significant
	C	17·4±0·3	Ditto.
	D	24·5±1·3	Over A significant
Maruteru (West Godavari) .	A	19·1±1·2	
	B	..	
	C	25·8±2·2	Over A significant
	D	33·1±1·4	Ditto.
Pattambi (Malabar) . . .	A	14·6±1·1	
	B	12·8±0·9	
	C	19·2±1·5	Over A significant
	D	22·2±1·1	Ditto.
Berhampur (Ganjam) . .	A	16·7±0·6	
	B	19·8±0·8	Over A significant
	C	26·4±0·8	Ditto.
	D	25·4±0·1	Ditto.

Table V

Aleurone thickness of Co 1 crop in the seed-bed manurial experiments

Treatments	Thickness of aleurone layer in microns (means of six readings)						
	Seventh day		Sixteenth day		Thirtieth day		
	Dorsal side	Ventral side	Dorsal side	Ventral side	Dorsal side	Ventral side	
A . .	9·6±0·7	7·9±0·5	27·0±3·0	14·4±0·01	26·8±1·4	15·3±1·2	Difference highly significant
B . .	9·8±0·6	6·7±0·5	21·3±1·7	13·8±1·7	43·1±1·0	18·0±0·01	

AN INVESTIGATION INTO THE ALGAL-FLORA OF PADDY FIELD SOILS OF THE UNITED PROVINCES, I*

BY

RAMA NAGINA SINGH, M.Sc.

Research Scholar, Department of Botany, Benares Hindu University

(Received for publication on 14th July 1938)

Introduction

During recent years a good deal of work has been done on the algal-flora of the soil. Among the notable investigations reference may be made to the work of Bristol [1920] on the algae of English soils, of Boye-Petersen [1935]-on the algae of the soils of East Greenland and Denmark, and of James [1935] on the algae of natural occurring soils from Redlands woods, Holmwood, Surrey, Shoreham, and Kent. In our country, however, such a work has almost been neglected and the only attempt in this direction has been that of Singh [1933] and Banerji [1935]. The former has worked on the algae of the naturally occurring soils of Lahore, while the latter has investigated the growth of the algae in the soils of an alluvial paddy field of Faridpur, Bengal. Work on the algae of uncultivated soils may not be of any economical value, but investigations of these lower plants from the soils of the Indian crops are likely to be both interesting and important, especially in relation to problems concerning soil biology and agriculture. The writer, therefore, thought it desirable to start investigations on soil algae in this Laboratory. As a beginning the cultivated soils of paddy fields of the United Provinces were taken. The results obtained by the writer are altogether different from those that have been recorded by Banerji, as will be clear from the remarks given at the end of this communication.

Technique

What matters greatly in the study of the soil algae is the device for taking up absolutely 'unmixed soil' from various depths. Consequently auger was used in this process and the sampling was done from four different districts of the United Provinces, *i.e.*, Benares, Mirzapur, Gorakhpur and Basti. In all four samples were collected, one from each district. Care has been taken not to sample the soils from isolated paddy fields but from large tracts, covering at least an area of five thousand acres. The samples from Benares were collected on the 18th of October, 1936, near Sakaldiha Station on the

* Contribution from the Department of Botany, Benares Hindu University.

E. I. Ry. Mirzapur samples were collected on the 9th of September, 1936, near Robertsganj, while those from Gorakhpur were obtained on the 15th of September, 1936, near Ramgarh Tal. The soil samples from Basti were collected on the 30th of September, 1936, near Khalilabad. These samples were taken from five different depths in the following order :—surface, two inches, six inches, twelve inches, and as far as the roots of the paddy plant penetrate the soil, and none was collected from a wet field. The samples were kept in glass specimen tubes and they were left in the vasculum till further use. During the intervals the soils got completely dried up, and this eliminated all such algae as could not resist prolonged desiccation.

Only one series of cultures of each sample were set, the culture medium being an aqueous mineral salt solution with the following composition :—Magnesium sulphate, 0·2 grm., potassium phosphate, 0·2 grm., ammonium nitrate, 0·5 grm., calcium chloride, 0·1 grm. and a trace of ferrous sulphate dissolved in 1,000 c.c. of distilled water. Milk-bottles were used for the cultures and the mouth of each bottle was plugged with cotton wool. Eight empty bottles were heated at a time in an autoclave at a pressure of one and a half atmospheres for fifteen minutes. After twenty-four hours the bottles were subjected to a second heating under the same pressure to ensure complete elimination of bacteria. One hundred and five such bottles were sterilised in this manner and in each one of them 150 c.c. of the culture solution was kept. The bottles were again heated in the autoclave twice in the manner described above. The sterilised solutions were then inoculated on the following day with different amounts of soils (*i.e.*, 10 grms., 5 grms., 2·5 grms., 0·15 grm.) from each of the above-mentioned depths by means of a sterilised spatula. The mouths of all the bottles were then covered with brown paper tied tightly round the neck. The cultures for Mirzapur district were started on the 25th of October, 1936, those for Gorakhpur district on the 30th of October, 1936, those for Basti district on the 5th of November, 1936, and those for Benares district on the 11th of November, 1936. For the convenience of comparison the cultures were named A, B, C and D respectively.

For the study of diatoms the method employed by Bristol [1920] has been followed and this has proved to be very satisfactory. The material was placed in water on a glass-slide and broken up into very small pieces with a pair of needles. The water was allowed to evaporate slowly into the air, the slide being covered with a glass lid to prevent the access of dust. After twenty-four hours' drying the slide was placed in a tube containing boiling strong nitric acid and heated to remove all organic matter. After careful washing in water it was transferred through 95 per cent and absolute alcohol to xylol. The film of the diatoms still remaining attached to the slide was then mounted in Canada balsam. Owing to the minute size of most of these soil-diatoms the markings on the walls were extremely difficult to make out, hence later preparations were made using dammar lac as a mounting medium in order to secure a better definition of the walls.

Growth in culture

The first sign of growth was observed after different intervals, not only in different soils but even in the same soil. At first a white scum which consisted of bacteria gradually appeared on the surface of the culture. This scum next assumed a green tinge, while many green patches began to grow on the surface of the soil below. These patches became large and in due course the whole culture medium assumed a light green colour owing to the formation of free-floating unicells and filaments. The greenish scum also thickened gradually, and the sides of the bottles also became covered with a green or dark green gelatinous membrane. In bottles in which diatoms developed the surface of the soil assumed a dull brown colour.

Different genera and even different species of the same form were observed not to grow simultaneously in culture bottles containing the same type of soil. In the floating scum various unicells, such as, *Chlorococcum*, *Chlorella*, etc., appeared first and these were followed by *Protosiphon* and filaments of *Oscillatoria*. *Phormidium* and *Nostoc* came out next and grew in almost all the bottles. A week later *Lyngbya*, *Phormidium*, *Homoeothrix*, and *Cylindrospermum* made their appearance in succession. At the same time good many of the unicellular and filamentous green algae, *e.g.*, *Spirogyra*, *Oedogonium*, and members of the Chaetophorales grew up. Diatoms appeared early and continued to grow to the last. Moss protonema began to grow very early in nearly all the bottles but disappeared after a very short time. A list of algae found growing in the different bottles containing different samples of soil is given in Tables I-IV.

Growth was luxuriant in those bottles that were left undisturbed for some time, while it was very slow in such as were frequently handled for observations. Throughout November and December, 1936, there was practically no growth in the cultures. There was a slight growth of algae in January, 1937, while in the beginning of February, the growth was plentiful, though in very few species. In the middle of March the cultures showed the climax of growth of the different forms, and it was also noted that the growth was quicker in those bottles that were exposed to direct light than those that were given indirect or diffused light. In April last, however, the bottles had to be placed in diffused light as the direct rays of the sun proved very hot and impeded the growth. In the end of this month the algae began to degenerate and within the first fortnight or so most of the species of the green algae, especially those of *Spirogyra*, disappeared altogether. The *Chlorococcales* and species of *Protosiphon* staggered with the unfavourable conditions for a sufficiently long time, the latter ultimately forming cysts. The blue-green algae were the last to disappear.

As a general observation it may be stated that the algae grew much more favourably in those bottles which contained the least amount of soil, *i.e.*, 0·15 grm.

Systematic enumeration of the species observed growing in the cultures

Myxophyceae

I. Chroococcales

Chroococcaceae

Genus *Chroococcus* Nägeli

1. *Chroococcus minutus* (Kütz.) Näg. Geitler, in Rabenhorst's *Kryptogamenflora von Europa*, Band XIV, Cyanophyceae, 1930-32, p. 234, Fig. 113 *c*.

Lat. colon. cum vag., 8-9·9 μ ; long. colon. cum vag., 16·5-18 μ , Lat. cell., 3·3-5 μ ; long. cell., 4-6·6 μ ; Lat. cell. cum vag., 4-6 μ ; long. cell. cum vag., 5-9·9 μ.

The alga was found in cultures of all the four soil samples from 11-14 in. depth. It mostly grew at the bottom of the culture solution. Intermingled with this form were filaments of *Oscillatoria* and *Phormidium*.

II. Hormogoneales

Rivulariaceae

Genus *Homoeothrix* (Thuret) Kirchner

2. *Homoeothrix juliana* (Manegh.) Kirchner Geitler, *op. cit.*, 1930-32, p. 576, Fig. 359.

forma *tenuis* form. nov.

Lat. fil., 9·9-12 μ ; lat. trich., 6·6-7 μ ; long. cell., 3·3-4 μ.

The alga was found growing in cultures of samples A, B and D from 8-10 in. depth. It occurred along with *Oscillatoria*, and a large number of forms belonging to *Chlorococcales*.

The present alga differs from the type in possessing narrower trichomes and thicker sheath.

It forms a fairly thick substratum on the surface of the soil.

Genus *Gloeotrichia* Agardh

3. *Gloeotrichia intermedia* (Lemm.) Geitler. var. *kanwaense* Rao Rao, " The Myxophyceae of the United Provinces, India—II ", *Proc. Ind. Acad. Sci.*, Vol. III, No. 2, Sec. B, 1936, p. 168, Fig. 2, *A-C*.

Forma

Diam. strat., 1-12 mm. ; lat. trich., at base, 9·9-11 μ higher up, 3-5 μ ; long. cell., at base, 3·3-8 μ ; higher up, 4-9·9 μ ; lat. het., 10-13·5 μ ; long. het., 8-11·5 μ ; lat. spor. cum vag., 13-15 μ ; lat. spor., 12-15 μ ; long. spor., 54·5-63 μ ; crass. vag., 0·8-1 μ.

This alga appeared in many of the cultures of all the four samples from 2-8 in. depth together with *Nostoc* and *Protosiphon*. The growth consisted of pale yellowish green rounded masses on the surface of the soil.

The thicker sheath, at the base of the filament above the spore, in which the alga differs from the type is possibly due to the disintegration of the vegetative cells there.

Nostocaceae

Genus *Cylindrospermum* Kuetzing

4. *Cylindrospermum muscicola* Kütz. Frémy. "Les Myxophycées de Madagascar," *Annales de Cryptogamie Exotique*, t. iii. fasc. IV, 1930, p. 377, Fig. 313; Tilden, *Minnesota Algae*, Vol. I, 1910, pl. X, Fig. 6; Ghose, "On some Myxophyceae from Rangoon", *Jour. Burma Res. Soc.*, Vol. XV, Part III, 1926, pl. VII, Fig. 15.

Forma

Lat. cell., 3·3-4·6 μ; long. cell., 4·5-6·6 μ; lat. het., 3·3-5 μ; long. het. 6·6-7·8 μ; lat. spor., 9·2-12·6 μ; long. spor., 13·2-20·3 μ.

The alga appeared in many of the cultures of all the four samples from 2-8 in. depth. It forms a dark brown patch on the surface of the soil.

It differs from the type in possessing slightly narrower and longer heterocysts and in the longer cells.

Genus *Nostoc* Vaucher

5. *Nostoc carneum* forma minor Bhâradwâja Bhâradwâja, "The Myxophyceae of the United Provinces, India.—I, "*Proc. Ind. Acad. Sci.*, Vol. II, No. 1, Sect. B, 1935, p. 102.

Lat. trich., 3-4 μ; lat. het., 4·6-5·4 μ; long. het., 4·2-6·4 μ; lat. spor. 4-6·4 μ; long. spor., 5-9·9 μ.

The alga appeared in many of the cultures of all the samples from 2-6 in. depth. It forms a pale green mass on the surface of the soil.

6. *Nostoc ellipsosporum* Rabenh. Geitler, *op. cit.*, 1930-32, p. 842, Fig. 533.

Lat. cell., 3-3·3 μ; long. cell., 3·3-8 μ; lat. het., 4·4-6·6 μ; long. het., 8·2-9·9 μ; lat. spor., 6·6-8·5 μ; long spor., 10-13·2 μ.

The alga appeared in nearly most of the cultures of all the samples from 8 in. depth. It forms spherical to formless, strong, spreading, olive-green to green plant mass on the surface of the soil.

Oscillatoriaceae

Genus *Oscillatoria* Vauch.

7. *Oscillatoria terebriformis* Ag. Geitler, *op. cit.*, 1930-32, p. 955, Fig. 607, *d*.

Lat. trich., 4·5-6·6 μ; long. cell., 1·7-4·6 μ.

The alga was found growing together with sterile filaments of *Oedogonium* in many of the cultures in all the samples from 2 in. depth. It forms a thin blue green covering over the surface of the soil. It differs from the type in possessing shorter cells.

8. *Oscillatoria variabilis* Rao Rao *op. cit.*, 1936, p. 172, Fig. 3, *A-D.*

Forma

Lat. trich., 6·2-6·6 μ ; long. cell., 3-3·3 μ.

The form possesses slightly broader trichomes. It differs from the type in having only rounded apical cells.

The alga was found in cultures of all the four samples from 11-14 in. depth. It mostly grew at the bottom of the culture solution intermingled with filaments of *Phormidium luridum* (Kütz) Gom., and other species of *Oscillatoria.*

9. *Oscillatoria proboscida* Gom. Geitler, *op. cit.*, 1930-32, p. 943, Fig. 598, *b.*

Lat. trich., 13·2-14 μ ; long. cell., 3·3-4 μ.

The alga appeared in several of the cultures of all the samples from 11-14 in. depth together with *Phormidium luridum* (Kütz.) Gom. and *Oscillatoria variabilis* Rao.

10. *Oscillatoria quadripunctulata* var. *unigranulata* Singh Singh, "The Myxophyceae of the United Provinces, India. IV".—*Proc. Ind. Acad. Sci.*, 1939, Vol. 9, No. 1, Fig. I, *F.*

Lat. trich., 1-1·7 μ ; long. cell., 7-8·3 μ.

The alga appeared in many of the cultures of all the samples from 11-14 in. depth together with other species of *Oscillatoria* and *Phormidium.*

The alga differs from the type in the possession of longer cells and single granule on either side of the septum.

Genus *Phormidium* Kütz.

11. *Phormidium Retzii* (Ag.) Gom. Geitler, *op. cit.*, 1930-32, p. 1012, Fig. 647, *a-d.*

Lat. fil., 12-13·2 μ ; lat. trich., 8-9·9 μ ; long. cell., 4·9-9·9 μ.

The alga was found growing in all the samples and in several of the cultures from 2-6 in. depth. It forms a dark bluish green thin layer over the surface of the soil.

The alga differs from the type in possessing indistinct tapering end-cells without any membrane.

12. *Phormidium luridum* (Kütz.) Gom. Geitler, *op. cit.*, 1930-32, p. 1010, Fig. 645, *a.*

Lat. trich., 1·5-3 μ ; long. cell., 1·5-4·2 μ.

The alga was found growing in many of the cultures of all the samples from 11-14 in. depth together with *Chroococcus minutus* (Kütz.) Näg. and filaments of *Oscillatoria*. It forms a blue green layer on the surface of the soil.

The alga differs from the type in the dimensions and in possessing straight tapering end-cells.

Genus *Lyngbya* C. Agardh

13. *Lyngbya limnetica* Lemm. Geitler, *op. cit.*, 1930-32, p. 1045, Fig. 661, *a-b*.

Lat. fil., 2-3·3 μ ; lat. trich., 1·5-1·7 μ ; long. cell., 1·99-2·49 μ.

The alga was found growing in many of the cultures of A, C and D samples from 12-14 in. depth. If forms a purple thin layer on the surface of the soil.

The alga differs from the type in having longer cells and in the end-cells being slightly tapering.

Genus *Microcoleus* Desmazierea

14. *Microcoleus chthonoplastes* Thuret. Geitler, *op. cit.*, 1930-32, p. 1134, Fig. 739 ; Bhâradwâja, " The Myxophyceae of the United Provinces, India.—I, " *Proc. Ind. Acad. Sci.*, Vol. II, No. 1, Sec. B, 1935, p. 98, Fig. 2, *b* and *c*.

Lat. cell., 3·4-4 μ ; lat. vag., up to 20 μ.

This alga appeared together with filaments of *Oscillatoria* in nearly most of the cultures from 6 in. depth. It forms a beautiful bluish green stratum on the surface of the soil.

Chlorophyceae

Volvocales

Chlamydomonadineae

Chlamydomonadaceae

Genus *Chlamydomonas* Ehrenberg

1. *Chlamydomonas intermedia* Chodat Pascher, in Pascher's *Süsswasserflora Deutschlands, Österreichs und Der Schweiz.*, Heft 4, 1927, p. 202, Fig. 141, *a-r*.

Lat. cell., 12-16 μ ; long. cell., 18-25 μ.

The alga appeared in many of the cultures of all the samples from 2-6 in. depth.

Chlorococcales

Chlorococcaceae

Genus *Chlorochytrium* Cohn.

2. *Chlorochytrium paradoxum* (Klebs) G. S. West James, " An investiga-

tion of the algal growth in some naturally occurring soils " *Beiheften zum Botanischen Centralblatt*, Bd. LIII, Abt. A, Heft 3, 1935, p. 527, Fig. 3, *A-E*.

Diam. smaller cells., 9·9-13·2 μ ; diam. larger cells., 23·3-30 μ ; lat. spor., 3·3-4·9 μ ; long. spor., 6·6-8 μ.

The alga was found growing in nearly all the cultures of all the samples from 2-6 in. depth in association with *Chlorella vulgaris* Beyerinck and *Chlorococcum infusionum* (Schrank) Meneghini. It forms a green papery substratum upon the surface of the culture solution.

Genus *Characium* A. Braun

3. *Characium nasutum* Rabenhorst Lemmermann, Brunnthaler und Pascher in Pascher's *Süsswasserflora Deutschlands, Österreichs und Der Schweiz*, 1915, Heft 5, p. 79, Fig. 15.

Lat. cell., 18-20 μ ; long. cell., 40-70 μ.

The alga was found growing as an epiphyte on *Oedogonium* filaments in many of the cultures of all the samples from 2 in. depth. Sometimes it forms a cluster. It differs from the type in possessing smaller cells.

4. *Characium acuminatum* A. Braun Lemmermann, Brunnthaler und Pascher, *op. cit.*, 1915, Heft 5, p. 79, Fig. 18.

Lat. cell., 10-15 μ ; long. cell., 20-35 μ.

The alga was found growing in many of the cultures of all the samples from 2-6 in. depth in association with *Chlorococcum infusionum* (Schrank) Meneghini. and *Chlorella vulgaris* Beyerinck.

Genus *Chlorococcum* Fries.

5. *Chlorococcum infusionum* (Schrank) Meneghini. Lemmermann, Brunnthaler und Pascher, *op. cit.*, 1915, Heft. 5, p. 63, Fig. 2.

Diam. cell., 15-40 μ ; lat. spor., 2-3 μ ; long. spor., 5-6 μ.

The alga appeared in nearly all the cultures of all the samples from 2-6 in. depth. It forms a fairly thick green layer upon the surface of the culture solution. It is found in association with *Chlorochytrium paradoxum* (Klebs) G. S. West and *Chlorella vulgaris* Beyerinck.

Chlorellaceae

Genus *Chlorella* Beyerinck

6. *Chlorella vulgaris* Beyerinck Lemmermann, Brunnthaler und Pascher, *op. cit.*, 1915, Heft 5, p. 112, Fig. 71.

Diam. cell., 6·6-9 μ (12 μ).

The alga was found growing in nearly all the cultures of all the samples from 2-6 in. depth. It forms a green layer upon the surface of the culture solution together with *Chlorochytrium paradoxum* (Klebs) G. S. West and *Chlorococcum infusionum* (Schrank) Meneghini.

Genus *Trochiscia* Kütz.

7. *Trochiscia reticularis* (Reinsch.) Hansg. James, *op. cit.*, 1935, p. 527, Fig. 3, *H-K*.

Diam. cell., 12-18 (up to 28) μ.

The alga appeared only in cultures of sample A from 2 in. depth. The cells were found scattered as well as aggregated to form a palmelloid colony in association with *Chlorococcum* and *Chlorella*.

The alga agrees with the type described by James in the diameter of the cells, in possessing single irregular reticulate chloroplast with a single pyrenoid. But, it differs from the same in the following points :—

(i) In all the cells (young and old cells) there is a third smooth laver external to the sculptured-wall.

(ii) The sculptured-wall consists of a network of regular ridges.

The palmelloid state and the autospores have been noticed.

Hydrodictyaceae

Genus *Pediastrum* Meyen.

8. *Pediastrum clathratum* var. *duodenarium* (Bailey) Lemmermann Lemmermann, Brunnthaler und Pascher, *op. cit.*, 1915, Heft 5, Fig. 56, *C*.

Colon. of 12-18 cells., diam. colon., 45-50 μ.

The alga was found growing among the *Oddogonium* filaments in many of the cultures of all the samples from 2 in. depth.

Chaetophorales

Trentepohliaceae

Gongrosireae

Genus *Gongrosira* Kütz.

9. *Gongrosira terricola* Bristol Bristol, "On the Alga-Flora of some Desiccated English Soils," *Ann. Bot.*, No. CXXXIV, 1920. Pl. II.

Lat. cell., 7-15 μ ; long. cell., 10-18 μ ; diam. zoogonidang., 15-18 μ.

The alga appeared in many of the cultures of all the samples from 12-14 in. depth. It forms a thin papery incrustation on the surface of the culture solution together with *Protosiphon botryoides* (Kützing) Klebs forma *parieticola* Iyengar.

It agrees with the type in forming an expanded stratum, the creeping filaments of which are closely interwoven to form a pseudo-parenchymatous disc of distended cells, in short and tapering upright filaments with obtuse apices and irregular branching, in possessing a band-shaped chloroplast with one to two pyrenoids and in sub-spherical basal or rarely intercalary zoogonidangia.

10. *Gongrosira circinnata* (Borzi) Schmidle Heering in Pascher's *Süsswasserflora Deutschlands, Österreichs und Der Schweiz*, 1914, Heft 6, p. 112, Fig. 161, *a & b*.

Diam. cell., 9·9-12 μ.

The alga appeared together with *Gongrosira terricola* Bristol and *Protosiphon botryoides* (Kützing) Klebs forma *parieticola* Iyengar in many of the cultures of all the samples of soil from 12-14 in. depth. The branching filaments of this alga appeared to come out from the pseudo-parenchymatous discs of *Gongrosira terricola* Bristol.

Genus *Pleurastrum* Chodat

11. *Pleurastrum constipatum* Printz Printz, "Subäerial Algae from South Africa," *Norske Videnskabers Selskabs Skrifter*, 1920, Nr. I, Pl. III, Fig. 124-155.

Diam. cell., 7-8·9 μ.

The alga was found growing together with *Gongrosira terricola* Bristol and *Protosiphon botryoides* forma *parieticola* Iyengar in many of the cultures of all the samples from 12 in. depth. It forms a green to yellowish green mucilaginous stratum on the surface of the culture solution.

12. *Pleurastrum insigne* Chod. Heering, *op. cit.*, 1914, Heft 6, p. 112, Fig. 166, *a, b & c*.

Lat. cell., 5-8 μ ; long. cell., 7-10 μ.

The alga was found growing together with *Chlorella vulgaris* Beyerinck and *Chlorococcum infusionum* (Schrank) Meneghini in many of the cultures of all the samples from 2 in. depth. It forms a mucilaginous green papery layer on the surface of the culture solution.

Oedogoniales

Genus *Oedogonium* Link

13. *Oedogonium intermedium* Wittrock Hirn, *Monographie und Iconographie der Oedogoniaceen*, 1900, p. 94, Pl. V, Fig. 31 ; Tiffany, *The Oedogoniaceae*, Ohio, 1930, p. 72, Pl. XIV., Fig. 134.

Forma

Lat. cell., 14·2-16·5 μ ; long. cell., 30-37 μ ; crass. oog., 26·4-30 μ ; long. oog., 30-34 μ ; crass. oosp., 26·4-27 μ ; long. oosp., 26·4-27 μ ; lat. anth., 13·2-14·5 μ ; long. anth., 6·6-13 μ.

The alga was found growing with filaments of *Spirogyra* in many of the cultures of all the samples from 2-6 in. depth. It differs from the type in smaller dimensions.

14. *Oedogonium hirnii* Gutwinski Hirn, *op. cit.*, 1900, p. 93, Pl. V, Fig. 29 ; Tiffany, *op. cit.*, 1930, p. 73, Pl. XIV, Figs. 136 and 137.

Forma

Lat. cell., 9·9-13·2 μ ; long. cell., 33·3-56 μ ; crass. oog., 33-34 μ ; long. oog., 33·3-40 μ ; crass. oosp., 26·4-28 μ ; long. oosp ; 26·4-28 μ ; crass. anth., 9·9-10·5 μ ; long. anth., 3·3-4·2 μ.

The alga was found growing in many of the cultures from 2-6 in. depth. The form differs from the type in smaller oospores and antheridia.

Conjugales

Euconjugateae

Zygnemaceae

Genus *Spirogyra* Link

15. *Spirogyra* sp.

Lat. cell., 45-50 μ ; long. cell., 225-230 μ.

The alga was found growing together with *Oedogonium* and other spp. of *Spirogyra* in nearly all the cultures of all the samples of soil from 2 in. depth.

The vegetative cells are 5-6 times as long as broad ; end-walls are replicate and chloroplasts are four in number.

The zygospores were not formed, hence the sp. could not be determined.

16. *Spirogyra* sp.

Lat. cell. 22·5-25 μ ; long. cell., 210-225 μ.

The alga was found growing together with other spp. of *Spirogyra* in many of the cultures of all the samples from 2 in. depth.

The vegetative cells are 5-6 times as long as broad ; end-walls are replicate and the chloroplast is single.

The zygospores were not formed, hence the species could not be determined.

Siphonales

Protosiphonaceae

Genus *Protosiphon* Klebs

17. *Protosiphon botryoides* (Kütz.) Klebs forma *parieticola* Iyengar Iyengar, " On an Indian form of *Protosiphon botryoides* Klebs, " *Archiv fur Protistenkunde*, Band 79, Heft 2, 1933, Fig. 1, *A-Z*.

Lat. vesicl., 40-60 μ ; long. vesicl., 80-100 μ ; lat. rhizoid., 10-36 μ ; long. rhizoid., 90-150 μ ; diam. cyst., 20-30 μ.

The alga was found growing in all the cultures of all the samples from 12-14 in. depth. It forms a papery gelatinous green scum on the surface of the culture solution.

The alga differs from the type in possessing shorter and somewhat broader rhizoidal portion and in the absolute absence of lamellation in the walls.

Bacillariophyceae

Pennales

Araphidineae

Fragilariaceae

Tabellarioideae

Fragilarioideae

Genus *Synedra* Ehrenberg

1. *Synedra ulna* var. *amphirhynchus* (Ehr.) Grun. Hustedt, " Die Kieselagen, Lieferung 1, and 2 in L. Rabenhorst's *Kryptogamen-Flora Deutschlands, Osterreich u. d. Schweiz*, B. VII, Leipzig, 1931-32, p. 197, Fig. 691 A, *e*.

Lat. frust., 6·6-9·9 μ ; long. frust., 118-200 μ ; striae, 10-12 in 10 μ.

2. *Synedra ulna* var. *spathulata* Grun. Hustedt, *op. cit.*, 1932, p. 197, Fig. 691A, *h*.

Lat. frust., 13·2-16·5 μ ; long. frust., 230-244 μ ; striae, 9-10 in 10 μ.

Biraphidineae

Naviculaceae

Naviculoideae

Genus *Anomoeoneis* Pfitzer

3. *Anomoeoneis sphaerophora* (Kütz.) Printz. West and Fritsch, " The British Freshwater Algae," Cambridge, 1927, p. 372, Fig. 156, *c*.

Lat. frust., 8-9·9 μ ; long. frust., 30-35 μ.

Genus *Navicula* Bory

4. *Navicula radiosa* var. *acuta* Grun. Majeed, " The Freshwater Algae of the Punjab, " Part I, 1935, Pl. II, Fig. 19.

Lat. frust., 6·6-7 μ ; long frust., 35-36·3 μ ; striae, 10-12 in 10 μ.

Genus *Pinnularia* Ehrenberg

5. *Pinnularia interrupta* Smith Smith, " A Synopsis of the British Diatomaceae," Vols. I and II, London, 1853, p. 59, Pl. XIX, Fig. 184.

Lat. frust., 4·9-5·3 μ ; long. frust., 29·7-30·5 μ ; striae, 10 in 10 μ.

The alga differs from the type in possessing smaller dimensions.

6. *Pinnularia major* Smith Smith, *op. cit.*, 1853, p. 54, Pl. XVIII, Fig. 162.

Forma

Lat. frust., 9·9-10·5 μ ; long. frust., 59-65 μ ; striae, 12-13 in 10 μ.

The form differs from the type in smaller dimensions.

7. *Pinnularia subcapitata* Greg. var. *paucistriata*. James, *op. cit.*, Heft 3, 1935, p. 545, Fig. 12, *C-D*.

Lat. frust., 4·5-5 μ ; long. frust., 32-34 μ ; striae, 9-10 in 10 μ.

Gomphocymbelloideae

Genus *Amphora* Ehrenberg

8. *Amphora ovalis* var. *gracilis* V. H. Majeed, *op. cit.*, 1935, Pl. IV, Fig. 7.

Lat. frust., 10-12 μ ; long. frust., 16·5-20 μ ; striae. 10-14 in 10 μ.

Genus *Cymbella* Agardh

9. *Cymbella Ehrenbergii* Kütz. Smith, *op. cit.*, 1853, p. 17, Pl. II, Fig. 21.

Lat. frust., 19·5-20 μ ; long. frust., 85-90 μ ; striae, 6-7 in 10 μ.

10. *Cymbella ventricosa* Kütz. Majeed, *op. cit.*, 1935, Pl. III, Figs. 11, 12 and 13.

Lat. frust., 6·5-7 μ ; long. frust., 23-25 μ ; striae, 10-12 in 10 μ.

Epithemiaceae

Rhopalodioideae

Genus *Rhopalodia* O. Muller

11. *Rhopalodia gibba* (Ehr.) O. Mull. West and Fritsch, *op. cit.*, 1927, p. 381, Fig. 163, *A*.

TABLE I

Date of inoculation, October 26, 1936; Date of examination, January 20, 1937; Depth to which the roots of paddy plants reach the soil, 12-15 in.

Names of algae growing	Surface				2 in.				6 in.				12 in.				As far as the roots of paddy plants reach the soil			
	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.
Chroococcus minutus															×	×		×		×
Homoeothrix juliana														×		×	×		×	×
Glocotrichia intermedia						×		×		×	×	×								
Cylindrospermum muscicola		–	×		×		×	×			×	×								
Nostoc carneum											×	×			×	×	×	×	×	×
Nostoc ellipsosporum											×	×			×	×	×	×	×	×
Oscillatoria terebriformis		×			×		×	×												
Oscillatoria variabilis													×		×	×		×	×	×
Oscillatoria proboscida													×	×	×		×		×	×
Oscillatoria quadripunctulata var. *unigranulata*														×	×	×		×	×	×
Phormidium Retzii													×	×	×	×		×	×	×
Phormidium luridum														×	×		×		×	×
Lyngbya limnetica													×		×	×		×	×	×
Microcoleus chthonoplastes														×	×	×		×	×	×
Chlamydomonas intermedia				×		×	×	×	×		×	×								
Chlorochytrium paradoxum					×	×		×		×	×	×								
Characium nasutum						×	×	×												
Characium acuminatum							×	×		×	×	×								
Chlorococcum infusionum						×	×	×		×	×	×								
Chlorella vulgaris							×	×	×	×	×	×								
Trochiscia reticularis					×	×	×	×												
Pediastrum clathratum var. *duodenarium*					×	×	×	×												

| | | |

TABLE II

Date of inoculation, October 30, 1936 ; Date of examination, January 28, 1937 ; Depth to which the roots of paddy plants reach the soil, 14-18 in.

Names of algae growing	Surface				2 in.				6 in.				12 in.				As far as the roots of the paddy plants reach the soil			
	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.
Chroococcus minutus														×	×	×		×	×	×
Homoeothrix juliana														×	×	×				
Gloeotrichia intermedia						×	×	×		×		×				×	×			
Cylindrospermum muscicola							×	×			×	×	×		×	×				
Nostoc carneum										×	×	×		×	×	×				
Nostoc ellipsosporum										×	×	×	×	×	×	×				
Oscillatoria terebriformis			×	×		×	×	×			×	×			×	×				
Oscillatoria variabilis												×		×	×	×		×	×	×
Oscillatoria proboscida								×		×		×	×	×	×	×		×	×	×
Oscillatoria quadripunctulata var. *unigranulata*						×	×		×		×	×		×	×	×		×	×	×
Phormidium Retzii						×	×	×		×	×	×		×						
Phormidium luridum														×	×	×	×		×	×
Lyngbya limnetica																				
Microcoleus chthonoplastes							×	×		×	×	×								
Chlamydomonas intermedia					×		×	×	×		×	×	×	×						
Chlorochytrium paradoxum						×	×	×	×	×	×	×								
Characium nasutum						×	×	×			×	×								
Characium acuminatum					×		×	×		×	×	×								
Chlorococcum infusionum						×	×	×	×	×	×	×								
Chlorella vulgaris						×	×	×			×	×								
Trochiscia reticularis																				
Pediastrum clathratum var. *duodenarium*		×		×		×	×	×												

| | | |

TABLE III

Date of inoculation, **November 5, 1936** ; **Date of examination,** January 28, 1937 ; Depth to which the roots of paddy plants reach the soil, 13-17 in.

Names of algae growing	Surface				2 in.				6 in.				12 in.				As far as the roots of the paddy plants reach the soil			
	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.
Chroococcus minutus											×	×		×	×	×		×	×	×
Homoeothrix juliana																				
Gloeotrichia intermedia						×	×	×	×		×	×			×	×				
Cylindrospermum muscicola							×	×			×	×		×						
Nostoc carneum					×		×	×	×	×	×	×								
Nostoc ellipsosporum										×	×	×		×	×	×				
Oscillatoria terebriformis									×		×	×								
Oscillatoria variabilis		×		×		×	×	×												
Oscillatoria proboscida														×	×	×	×	×	×	×
Oscillatoria quadripunctulata var. *unigranulata*			×	×	×					×	×		×		×	×		×	×	×
Phormidium Retzii		×	×			×	×	×	×	×	×	×								
Phormidium luridum														×	×	×		×	×	×
Lyngbya limnetica														×	×	×	×	×	×	×
Microcoleus chthonoplastes															×	×		×	×	×
Chlamydomonas intermedia						×	×	×	×	×	×	×				×		×		
Chlorochytrium paradoxum							×	×		×		×		×	×					
Characium nasutum		×		×	×	×	×	×												
Characium acuminatum							×	×		×	×	×								
Chlorococcum infusionum						×	×	×	×		×	×	×							
Chlorella vulgaris					×	×	×	×	×		×	×		×	×					
Trochiscia reticularis																				
Pediastrum clathratum var. *duodenarium*			×	×		×	×	×												

| | | |

TABLE IV

Date of inoculation, November 11, 1936; Date of examination, January 30, 1937; Depth to which the roots of paddy plants reach the soil, 14-20 in.

Names of algae growing	Surface				2 in.				6 in.				12 in.				As far as the roots of the paddy plants reach the soil			
	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.	10 grm.	5 grm.	2·5 grm.	0·15 grm.
Chroococcus minutus										×		×			×	×		×	×	×
Homoeothrix juliana							×	×			×	×		×	×	×				
Gloeotrichia intermedia						×	×	×			×	×	×	×						
Cylindrospermum muscicola						×	×	×		×	×	×								
Nostoc carneum										×	×	×								
Nostoc ellipsosporum										×	×	×			×	×				
Oscillatoria terebriformis	×	×		×			×	×		×	×									
Oscillatoria variabilis												×			×				×	×
Oscillatoria proboscida											×			×	×			×	×	×
Oscillatoria quadripunctulata var. *unigranulata*														×	×	×		×	×	×
Phormidium Retzii											×	×								
Phormidium luridum																		×	×	×
Lyngbya limnetica																		×	×	×
Microcoleus chthonoplastes										×	×	×								
Chlamydomonas intermedia			×	×						×	×	×								
Chlorochytrium paradoxum									×			×								
Characium nasutum		×		×			×	×												
Characium acuminatum										×	×	×								
Chlorococcum infusionum									×		×	×								
Chlorella vulgaris							×	×			×	×								
Trochiscia reticularis																				
Pediastrum clathratum var. *duodenarium*				×		×	×	×												

| | | |

Nitzschiaceae

Nitzschioideae

Genus *Nitzschia* Hassall

12. *Nitzschia palea* (Kütz.) W. Smith Majeed, *op. cit.*, 1935, Pl. VI, Figs. 2 & 3.

Lat. frust., 3·3-4 μ ; long. frust., 29·7-30 μ.

Concluding remarks

In comparing the algal growth in these cultures with that obtained by Banerji [1935], a marked degree of dissimilarity is apparent.

In the first place, Banerji has not made any mention of the depth from which he sampled his soils. It seems from his statements that the soils were taken from the surface and in one case he has actually made cultures of mud. The value of the study of these algae with regard to their economy in soil and agriculture lies in the depth of the soil to which they grow—a point which has altogether been ignored by Banerji. The investigations of the writer [1939] on the Myxophyceae of U. P. and also those of Rao [1937] have conclusively shown that spp. of *Calothrix*, *Nostoc*, *Phormidium* and *Oscillatoria* are the commonest amongst the blue-greens found on the surface of the soil and in muddy waters. It is, therefore, natural that Banerji found *Calothrix Braunii*, *Nostoc* sp., *Phormidium corium* and P. *valderianum* in his soil cultures.

Secondly, Banerji has completely overlooked the conditions of the soil from which he set his cultures. He has taken into consideration the wet soils. The idea of such investigations is to bring out those algae which can resist prolonged desiccation and so can live normally under the surface of the soil for long periods. This fact is constantly emphasized by other workers on soil algae, especially by Bristol [1920], who left her soil samples for four to twenty-six weeks for drying before actually setting the cultures.

Thirdly, a symbiotic relationship between the algae and bacteria of the soil, a fact, which had long been stated by Kossowitsch [1894] and to which Banerji has referred to, is very much doubted at the present time. Fritsch [1936] is of opinion that " the algae in relation to nitrogen fixation beneath the illuminated zone of the soil must depend, in large measure, on their being in a condition of active growth and multiplication, and of that he believes no adequate proof has so far been presented ". He has also remarked that " a study of the surface community, therefore, should include not only the forms visible at the surface, but also those encountered at depths to which light is found to penetrate. It is not improbable that a microstratification of the

surface-living soil algae may be found to obtain, depending upon their immediate light requirements and upon their relative degree of susceptibility to desiccation. No data are at present available concerning the depth to which light can penetrate beneath the surface of a compact soil, but it is doubtful whether there is anything but darkness below the top few centimeters ".

Fourthly, Banerji reports that his cultures are especially rich in blue-green algae. He mentions the complete absence of diatoms and records only one member of the green algae, *i.e.*, *Pleurococcus Naegelii*.* The writer, during his investigations, has observed good many of the Myxophyceae growing, though represented by different forms from those mentioned by Banerji, excepting one, *i.e.*, *Phormidium luridum*. Again, the universal and widespread occurrence of diatoms has been noticed, as also of the large number of the Chlorophyceae.

Summary

The investigation by means of water cultures of four samples of soil from paddy fields of widely separated localities of the United Provinces has shown that there is a widely distributed ecological plant formation of moss protonema and algae.

The most important algae in this formation are *Chlorella vulgaris*, *Trochiscia reticularis*, *Gongrosira terricola*, *Oedogonium intermedium* and *Protosiphon botryoides* forma *parieticola*.

The total number of species and varieties found in these soils is forty-three, out of which are fourteen Myxophyceae, seventeen Chlorophyceae and twelve Bacillariophyceae. The soil samples had all been subjected to desiccation for four to five weeks before they were placed in the cultures.

In conclusion, I have much pleasure in expressing my great indebtedness to Professor Y. Bhâradwâja for his kind guidance and criticism throughout the course of this investigation.

REFERENCES

Banerji, J. C. (1935). *Sci. and Culture* **1**, No. 5

Boye-Petersen, J. (1935). *Dansk Botanisk Arkiv* **8**, No. 9

Bristol, B. M. (1920). *Ann. Bot.* **34**, 35-79

Fritsch, F. E. (1936). 'Essays in Geobotany in Honour of William Albert Setchell'

James, E. J. (1935). *Beiheften Zum Botanischen Centralblatt* **Bd. 53**, Abt. A, Heft. **3**, 519-533

Kossowitsch, P. (1894). *Bot. Zeit.*, Heft. **5**, 98-116

Rao, C. B. (1937). *Proc. Ind. Acad. Sci.* **6**, No. 6

Singh, Har Dyal (1933). *J. Ind. Bot. Soc.* **12**

Singh, R. N. (1939). *Proc. Ind. Acad. Sci.* **9**, No. 1.

* Banerji has written the name *Protococcus viridis*, but this is not in vogue at present. The current name is *Pleurococcus Naegelii* (*cf.* Fritsch " The Structure and Reproduction of Algae," 1935, p. 289).

ON THE PROBABILITY OF SEASONAL MIGRATION AMONG THE SOLITARY PHASE INDIVIDUALS OF *LOCUSTA MIGRATORIA* IN NORTH-WEST INDIA

BY

Y. RAMCHANDRA RAO, M.A., F.R.E.S.

Locust Research Entomologist

AND

DESRAJ BHATIA, M.Sc.

(Received for publication on 31st May 1938)

(With Plate V and one map)

Introduction

In connection with a scheme of Locust Research, which has been in progress since 1931 under the auspices of the Imperial Council of Agricultural Research in India, intensive surveys of various desert areas of Sind, Baluchistan, Rajputana and South-West Punjab are being carried out periodically by a special staff, with the object of studying the seasonal distribution and activities of the solitary phase of the Desert Locust (*Schistocerca gregaria* Forsk.) in North-West India. In the course of these surveys, the survey staff have in addition to the Desert Locust been meeting with solitary phase individuals of two other locusts, *viz.*, *Locusta migratoria* ph. *solitaria* (Migratory Locust), and *Patanga succincta* (Bombay Locust). No particular significance was, however, attached to this circumstance during the earlier years of the work, as it was generally thought that their presence, as indeed in the case of individuals of even the Desert Locust, was merely of an incidental character, presumably indicating the occurrence of local breeding and multiplication as a result of the development of favourable ecological conditions.

During the year 1935, however, fairly conclusive evidence was obtained as to the capacity of the solitary phase individuals of the Desert Locust to migrate long distances at different seasons of the year, whereby they generally succeeded in reaching suitable breeding places in a different rain-belt [Rao, 1936 and 1937]. Thus, *solitaria* individuals that had bred in spring in Baluchistan, or perhaps even in Iran, were, during that year, noticed appearing suddenly in the Sind-Rajputana areas in June-July, while the generation produced in the Indian Desert areas during summer and autumn of that year was observed gradually leaving these regions and migrating into Mekran during autumn and winter months. In the Sind-Rajputana regions, which is subject to summer rainfall, the Desert Locust population was found to be at its minimum during the dry months of the year, *viz.*, January to May ; while, in the regions of winter rainfall, especially in the hinterland of Baluchistan, the

minimum was reached during July to September. Detailed observations, continued during the years following, *viz.*, 1936 and 1937, have served to confirm the deductions made as to the existence of normal seasonal migration from one rain-belt to another in the Indo-Iranian areas, among the solitary phase individuals of *Schistocerca gregaria*.

The analogy of the deductions referred to above suggested the idea that the occasional records of captures of stray specimens of the Migratory Locust and the Bombay Locust might perhaps be attributable to the occurrence of a somewhat similar migration of the *solitaria* individuals from one part of the country to another. All the data recorded during the past few years, in regard to the occurrence of these two species of locusts in their *solitaria* phase in the regions under regular observation, were, therefore, collected together, analysed and correlated with meteorological and other data. It is the aim of this note to set forth the inferences made as a result of these studies.

Available data for the Bombay Locust, *Patanga succincta* L.

All the information available has been classified in Table I (Appendix), from a study of which it would be seen that the data on hand are comparatively scanty. It is, however, rather significant that all the specimens had been collected either from the Sind-Rajputana Desert areas or from the Cutch-Kathiawar region, and that none had been found in the Baluchistan region with the single exception of an individual captured in March last (1938) at Dadhar at the entrance of the Bolan Valley—presumably the extreme limit of its distribution towards the west. Most of the specimens were, moreover, collected either in autumn, winter or early spring, and none had been noticed during the months of the summer monsoon (with the exception of one found at Nokh on the 4th June 1935). Hoppers have not as yet been detected anywhere in these areas.

Stray specimens of solitary phase individuals of *Patanga* have been observed in the past at Coimbatore, Nilgiris and a few other localities in South India, and the senior author found a few specimens of the solitary phase of the Bombay Locust collected in the past at Pusa and elsewhere among the locust collections of the Imperial Entomologist at New Delhi. It is, therefore, evident that the area of distribution of this species in India is fairly wide. Outside Indian limits, it is known to occur in Ceylon, China, Sumatra, Java and Borneo [Kirby, 1914], and according to Uvarov [1928] it is distributed all over Southern and South-eastern Asia, and the Malay Archipelago.

According to Lefroy [1906], the locust has only one brood in the year, which occurs during the monsoon season, *i.e.*, between June and September. The swarms breed in open, grass areas in the midst of the forest regions of the Western Ghats, and eggs are preferably laid in soft, clay soils. The adults of the new generation are said to migrate into forests in autumn, remain inactive there during the cold months, and go through a second period of migratory activity in the spring months of March, April and May, flying back to the forests

for breeding by the beginning of the monsoon. It is rather noteworthy that the times of incidence of the *solitaria* forms in the desert areas correspond more or less with the periods of migration noted above, in the case of the *gregaria* swarms. In the absence, however, of fuller information in regard to its distribution in other parts of India, and in view, moreover, of a complete lack of knowledge of the breeding grounds of its solitary phase, it is not possible to appraise the proper significance of the data detailed above.

Data for the Migratory Locust

All available data on *Locusta* have been presented in Table II (Appendix), classified according to the years and seasons of incidence and the regions of occurrence. Information for the earlier years, *viz.*, 1931 to 1935 is quite fragmentary, and much of it has been gathered from notes recorded on the labels of specimens collected during this period. For the years 1936 to 1938, however, fuller information has been available, mainly owing to the observations made by the junior author during this period.

A study of the classified data in Table II would show that, in general specimens of the Migratory Locust are found to be common in the Sind-Rajputana areas only during the monsoon months, while in the Baluchistan region, they are more often met with in the spring season. It is also apparent that breeding occurs generally after receipt of good rainfall, and that few specimens are met with in seasons of drought.

(*a*) Period from 1931 to 1935

Year 1931

No data are available for the Sind-Rajputana region. In the Baluchistan areas, spring rainfall was fairly satisfactory, and Dr. M. Sharif found a few adults in April at Pasni and Ormara, and observed in May, a few hoppers as well as adults at Panjgur. In July, several adults were collected at Sharigh—a locality subject to monsoon rainfall—and in August, a specimen was noted at Dasht Thana near Kolpur (Quetta-Bolan area), and another at Jhatpat on the Sind borders.

Year 1932

In April, a few adults were collected at Quetta and one at Pasni ; and in September, a few hoppers and adults were observed in Kolwah (Mekran) in the wake of fairly heavy falls in July. In November an adult was collected at Khairpur in the Bahawalpore State ; and near Sodakhor in the Jaisalmer Desert, the senior author observed a few adults along with nineteen specimens of the Desert Locust, in the course of the survey of an open, grassy area at the end of November. The individuals of the Desert Locust were apparently representative of a summer generation bred in north-east Rajputana, which were presumably in the course of their migration towards the west—remarks that might equally apply to the *Locusta* individuals.

Year 1933

A few adults were observed at Akil in west Sind in February, and were probably overwintered individuals. In April, a few adult specimens were found at Pasni. There were fairly heavy spring rains in Mekran in February-April 1933, and since good numbers of *Locusta* adults were observed in the Turbat-Panjgur region in July, it is presumed that breeding had taken place in this region in late spring. As there was good rainfall also during July-August in the Mekran hinterland in 1933, considerable breeding of *Locusta* had presumably taken place in the valleys of the interior, as corroborated by the circumstance that good numbers of adults were collected in Kolwah, Kech, Panjgur and Kalmat during August, September, October and November. A few adults were found in July-August in Kachhi and Lasbela also. In the summer rainfall areas of Sind and Rajputana, a fair number of adults were found in May (Akil), in June (Fort Abbas), and in July (in the areas of west Sind and Bikaner). At the beginning of July 1933, the junior author noted several *Locusta* adults at Shah Hassan in the Manchar Lake region of Sind near the borders of Baluchistan. He was also told that a small swarm of locusts had been seen in this region, and though there was no confirmation of this report, it is not improbable that the species concerned might have been *Locusta migratoria* ph. *solitaria*, flying about in small groups. *Locusta* adults were noted in good numbers between August and December in various places in the Sind-Rajputana area, such as, Bahawalpur, Bhatinda, Thar area, Jaisalmer area, west Sind and Khairpur, and Dera Ghazi Khan and Dera Ismail Khan Districts. As the monsoon was heavy and continuous, there were doubtless two consecutive generations of *Locusta* during the period between July and November in the desert areas.

Year 1934

Drought prevailed in Mekran in spring and no adults were observed in Mekran and Upper Baluchistan between January and June except for a single adult collected in May at Panjgur. In the eastern areas, one specimen was found in April at Mirzapur in west Sind, and in May, a few were found in the Cutch State, and in the Bikaner and Bahawalpur areas. In Mekran, one specimen was collected at Pasni in July. In the Indian Desert areas, the monsoon set in rather early in the latter half of June and continued till the first fortnight of September, but was, on the whole, rather light. In the Thar area of Sind, adults were observed in several places in July, and hoppers were found at Chachro and Rahimki Bazar in August in fields of *bajri* (*Pennisetum typhoideum*). In July both hoppers and adults were sent in from the Ludhiana-Patiala area of Punjab by a correspondent. A few adults were collected also from Sikar (Jaipur State) and Saro (Thar) in September and in October from Dirasar (Bikaner State). An adult was collected at Hingol (Lasbela State) in November 1934.

Year 1935

In February and March, 1935, a thorough search was made at Chachro and Rahimki Bazar respectively for specimens of hibernating locusts among

bushes and under field fences, in localities where breeding had been observed in 1934, but neither *Locusta* nor *Schistocerca* was found at these places, though certain large grasshoppers were found hiding under the fences. This would probably indicate that the individuals of *Locusta* of the new generation produced in July-August 1934 had, as in the case of *Schistocerca*, left the area by the autumn of that year. A single adult collected in March 1935, at Sardarshahr in the Bikaner area in the northern Desert is, however, found in the collections. In spite of heavy winter rainfall in the Mekran, the only records, in regard to the Baluchistan area, are of an adult found in May 1935 at Mand in the Kech Valley, and another collected at Liari in Lasbela State in June 1935. During the summer season, there is only one record of an adult found at Nokh in July for the Rajputana area. The paucity of *Locusta* individuals in both the Baluchistan and Rajputana areas in a year, in which the *Schistocerca* population had increased enormously all over these regions, is rather remarkable. It may, however, be noted that the monsoon did not extend into Mekran, Lasbela and Sind in the summer of 1935, nor was the rainfall in the Desert areas considerable except in July.

(*b*) Period from 1936 to 1938

The extensive observations made by the junior author have served to furnish considerable information in regard to the developments of the Migratory Locust during this period.

Year 1936

There are no records of observations on either adults or hoppers of *Locusta* during the first six months of 1936, in the Baluchistan or the desert areas, except for one specimen noted on the 29th June 1936 at Udasar in Bikaner.

In July 1936, however, adults varying in number from one to one hundred were found in *jowari* (sorghum) fields at Bhag, Gandhawa, etc., in the Kachhi area and at Johi in the west Sind area, indicating that breeding had occurred along the Baluchistan-Sind borders during the spring months of 1936 as a result of favourable rainfall. During August and September 1936, fairly good numbers of *Locusta* were noted during surveys along with individuals of *Schistocerca* in the Thar-Mallani, and Bikaner-Jaisalmer areas. By the 24th of September, however, very few adults of either *Schistocerca* or *Locusta* were noticeable in the Thar-Mallani area, where owing to the development of adverse climatic conditions brought about by the prevalent drought, almost the whole bulk of the new generation of *Schistocerca*, produced during July-August, would seem to have deserted the area. Neither *Schistocerca* nor *Locusta* was seen in this area till June-July 1937.

In the northern areas of the Indian Desert, on the other hand, there was very heavy rainfall (about 15 inches in the course of about ten days) in August 1936, and this led to a considerable and rather protracted breeding of the Desert Locust, which consequently went through a second monsoon generation in this area between September and November. The adults of the second

generation would appear to have overwintered in this area, migrating therefrom, apparently westwards, only by February-March, 1937. No direct observations in regard to the breeding of *Locusta* at this part of the year are on record, but since as many as twenty-two individuals of *Locusta* were found in this area along with specimens of *Schistocerca* during October, November and December 1936, it is not unlikely that *Locusta* had also to a certain extent bred and overwintered in this area.

Year 1937-38

The areas of infestation in 1937-38 have been marked in the map. In the Indian desert areas, there are only three records of captures between January and May, 1937 : one found near Nokh in February, a second near Lathi (east Jaisalmer) in April, and a third at Nokh at the end of May.

1. Spring breeding.—In the Baluchistan area, no observations had been made during the months of January to April 1937, and it was more or less by accident that the junior author visited the Kachhi area during May, when he found both *Schistocerca* and *Locusta* breeding in fair numbers in this area. During June 1937, he found fairly good numbers of *Locusta* adults at Sibi, Dadhar and Mashkhaf. At Kirtha in the Bolan Valley, he found quite an intensive breeding of *Locusta* in June, among cultivated fields of *jowari* and water-melons, and among grasses in the vicinity. The density of population was estimated at over one million per square mile, and he could actually count seventy-seven *Locusta* adults and twenty-eight hoppers within a small portion—180 square yards in extent—of one of the fields. (It may be mentioned in this connection, that when the same area was re-visited in August 1937, a few adults only were found.)

A report accompanied by specimens received from the Tahsildar of Kohlu (a division of Sibi District in Baluchistan) indicated that hoppers and adults of *Locusta migratoria* as well as of certain grasshoppers (mainly *Oedaleus*), had been found in considerable numbers in the Kohlu valley during May-June 1937. Owing to the favourable distribution of rainfall in February, March and April (Table III—Appendix), it is quite probable that similar breeding of *Locusta* had extended into various other neighbouring hill-valleys of Baluchistan, such as those of Loralai and Sibi Districts and of the Marri-Bugti country.

During May, the Mekran Survey Assistant reported the presence of *Locusta* adults in the Kolwa valley of Mekran, and on the 29th June, one of the Survey Fieldmen found five *Locusta* adults at Nuskhi in Chagai District.

2. Summer brood.—In the desert area, very few specimens of *Locusta* were found in the desert along with *Schistocerca* during surveys made in June at the Nokh Outpost, whereas during July, as many as fifty individuals of *Locusta* were collected in association with an equal number of *Schistocerca* between the 1st and the 25th July, but from the 26th July both species became scarce at Nokh. At Phalodi, thirty-two miles south of Nokh, where a heavy fall of six inches of rain had been received on the 1st July, good numbers of *Locusta* hoppers were found on the 31st July in a grass-covered depression in the midst

FIG. 1. *Jowari* (sorghum) field severely defoliated by hoppers of *Locusta migratoria* L. at Moti Dau, Mehsana District, Baroda State (November 1937)

FIG. 2. Low-lying area covered with *Tephrosia* scrub and grasses at Sadulpur, Bikaner State, where large concentrations of *Locusta migratoria* ph. *solitaria* were seen on 10th July, 1937

of sand dunes, while small numbers of *Schistocerca* hoppers were found among bushes on the sides of the dunes. In the Thar-Mallani area, in the southern desert, small numbers of *Locusta* were found appearing in July 1937 along with individuals of the Desert Locust. Similarly, in the vicinity of Karachi too, both *Locusta* and *Schistocerca* were found occurring together in July, 1937, during local surveys.

In the East Bikaner area, neither *Locusta* nor *Schistocerca* adults were noted during a tour in the middle of May in the Nohar-Reni-Sadulpur section, but by July, fairly large concentrations of *Locusta* and somewhat smaller groups of *Schistocerca* were found at Nohar (3rd July) and at Sadulpur (9th and 10th July). In the latter place especially, the *Locusta* population, estimated at about 80,000 per square mile, occupied a very large extent of rather low-lying area, covered with a heavy growth of *Tephrosia* scrub and grasses (Plate V, fig. 2), while the Desert Locust concentrations (about 10,000 per square mile) were found on sand-mounds in slightly higher and drier situations.

On the other hand, few *Locusta* adults were noticeable in the Kachhi-Bolan area during July-August.

With the heavy rainfall received during the latter half of June and in July, *Locusta* hoppers were noticeable in greater or smaller numbers almost all over the desert regions, except in the Jaisalmer area. Specially large numbers of hoppers were noted along the eastern borders of the Desert as in the Reni-Sadulpur area of Bikaner, and the Shekawati area of Jaipur. The junior author, for instance, in the course of his examination of the Sadulpur neighbourhood, met with on the 11th August 1937 very large concentrations of hoppers and adults in certain places. By actually counting the number of hoppers and adults in measured plots of ground, he estimated the density of the *Locusta* population to be between one and three millions per square mile in the case of hoppers, and between two and four millions in the case of adults. In regard to the general colouration of the hoppers, he observed that it was mostly greenish, or green and brown, though in a certain number of them, he found the green replaced by reddish brown on the ventral surface, the reddish tinge being found extending also in some cases to the legs, the post-ocular streak and the pronotal stripe. He also found several other hoppers which had blackish brown dots interspersed on a background of grey brown and a few others which were of coal-black colour.

Similar dense concentrations of hoppers and adults were noted in August in the Jhunjhunu-Pilani area of the Jaipur State.

In most parts of the Indian Desert, there was a cessation of monsoon rainfall from the end of July till the 7th of September (Table III—Appendix), and as a result thereof conditions of drought prevailed, which began to affect cultivated fields as well as the natural vegetation, causing them to dry up. As high temperatures (for instance a maximum of 105°F. at Bikaner early in September) and comparatively low humidity prevailed during this period, it is surmised that the ecological conditions in these areas became uncongenial to adult locusts, and created in them an urge to abandon these

areas. As several dust or thunder storms passed over this area during the last week of August in the afternoons, the more mature forms of both *Schistocerca* and *Locusta* would appear to have migrated along with the storms out of the east Bikaner area. The decrease in numbers of the locusts was so evident that it had attracted the notice of the cultivators of the Sadulpur area, who declared, when enquiries were made during a visit at the beginning of September 1937, that '*phidkala*'—a local term denoting locust and grasshopper infestation—had considerably diminished in their fields for the past ten days. During September, fair numbers of *Locusta* adults, however, still persisted in the eastern desert areas, and small numbers were found in some places along the fringes of the desert, *e.g.*, Loharu, Bhiwani, Pataudi Road, Rewari, Reengus, Sikar, Jhunjhunu and Phulera, though, by October-November, very few *Locusta* adults were to be seen at the very places where they had been so abundant in August.

3. October infestation.—During October 1937, two reports of rather severe damage to rain-fed cereal crops were received—one from the Sirohi State and the other from the Mehsana District of the Baroda State. Both these areas were visited, the former by the junior and the latter by the senior author, and investigations were made. It was reported that flying swarms had not been seen anywhere, but that large numbers of hoppers, which had at first been mistaken for the young ones of ordinary grasshoppers (locally known as *khappadi*), were found damaging the crops in October. As a result of enquiries made, it was elicited that even old ryots (cultivators) could not recollect having seen a similar type of damage ever before, the attacks of the Desert Locust swarms fairly common in the Gujarat area being said to be altogether of a different character.

As a result of official enquiries made in the States adjoining Sirohi and Mehsana areas, and of a personal visit paid by the junior author to various localities in Kathiawar and Gujarat in December, 1937, it was found that the following localities had, in addition, been similarly infested at about the same period: *1. Palanpur State*: Some damage to *bajri* and *jowari* fields at Kuchawada village of Deesa Tahsil, and light damage to *jowari* at Umardeshi and Palanpur; *2. Idar State*: Paddy and *jowari* damaged in the villages of Panpur, Lalpur and Purbada in the western part of the State; altogether 120 acres of paddy and 128 acres of *jowari* were reported to have been damaged; *3. Kaira District, Gujarat*: A small block of rice fields in the Matar Taluka was reported to have been attacked in November. As regards the Sirohi and Mehsana areas, the following information was gathered in regard to the extent of damage: *Sirohi State*: Several villages in the Pamera and Mandhar Tahsils (mostly sand-loam areas) in the south-western part of the State were affected, of which four villages were badly damaged. *Bajri* (*Pennisetum typhoideum*) and *barti* (*Panicum miliaceum*) were more or less defoliated and the ears damaged, and many fields were said to have been prematurely harvested to save them from attack. Grass was also attacked. *Mehsana District*: The affected areas were situated in the Talukas of Mehsana, Kheralu and Vijapur, and were thus all located in the north-eastern quadrant of the Mehsana

District. The total area attacked was probably over 300 acres of cultivation which consisted mostly of *jowari*, and to a certain extent paddy, sugarcane and *bajri*. The worst attacked locality was Gundrasan, where several *jowari* fields were absolutely stripped of leaves (Plate V, fig. 1).

From the data available, the origin of the infestation may perhaps be traced as follows. There was good rainfall in the Sirohi and Gujarat areas during July, which was favourable for the early crops, such as *bajri*, *jowari* and pulses. Then followed a long drought in August, which was broken only on the 8th September, when a depression, originating in the Bay of Bengal and travelling north-east to south-west, ushered in heavy rainfall in Gujarat and Rajputana and it is surmised that a good proportion of the large *Locusta* population known to have been present in the areas of Eastern Rajputana were carried by the storms associated with the depression, into the areas of south-east Marwar, Sirohi, Idar, Palanpur and Mehsana. The transference of locust population would appear to have occurred not in the form of swarms, but as large groups of individuals. It is rather interesting to note that the regions infested, *viz.*, south-western Sirohi, Palanpur, Idar, and the north-eastern parts of Mehsana, form an area of undulating sandy loam country, 300 to 400 ft. above seal-level, abutting on the bases of the Abu and Aravalli ranges. The surface soil layers of this area are composed mostly of a thick mantle of fine sandy loam (or perhaps loess) deposited in the form of a succession of low dunes by aeolian action in a former drier age. The geographical position of the infested areas rather suggests that the body of migrating locusts, on emerging from the hilly tracts of S. E. Rajputana, lying to the north-east of the plains of Gujarat, had selected the nearest wet patches along the fringes of the sandy country for depositing their eggs. *Locusta migratoria* has restricted food-habits, and as a rule attacks only plants of the grass family. In Sirohi, it was found to attack *bajri* and *barti* (*Panicum miliaceum*), and in Gujarat, *jowari* (sorghum), sugarcane and rice. In addition, various wild grasses were also devoured. It is probable that the *Locusta* adults had, on arrival early in September, concentrated in fields of *bajri* and *jowari*, and as they were presumably already mature, they were able, almost immediately, to deposit eggs in the more moist situations among cultivation. Hoppers had probably emerged by the end of September and the beginning of October and begun to feed on the standing crops of *bajri*, *barti*, *jowari*, sugarcane and paddy before they were noticed and reported. Many of the hoppers had become adults by the end of October, and by November 10th, most of the adults had already disappeared from the scene of their activity. Though a fair number of bird or bat predators were noticeable, the diminution in numbers was so sudden that it could not have been solely due to the activity of natural enemies. Stray hoppers were, however, being found in these areas even in December, which would indicate that stray egg-laying had continued over a long period.

4. Second brood of Locusta *in the desert area.*—The fall of good rain in September, in the southern areas of the desert, led to the development of a second brood of *Locusta* in the Thar area, hoppers being found in fair numbers throughout October and the first week of November. Hoppers were similarly

observed in the Sanchore-Raniwara area adjoining the Sirohi area in November. At Chachro a sudden decrease in the population of *Locusta* adults was noticeable after the 10th November, and by the end of December, few specimens of *Locusta* were to be met with there.

We are indebted to Dr. Keshodas Baweja of Lyallpur for the information given by him in regard to the presence of fairly large numbers of *Locusta* adults in October on *sarkanda* (wild *Saccharum*) at Campbellpur (Attock District) in the Punjab, and since Dr. W. Burns, Agricultural Expert, Simla also found a few adults in September at Simla, it is possible that *Locusta* had also been breeding in various suitable grassy areas in Punjab during the monsoon period.

5. Distribution of Locusta *during November, December and January.*— During the second week of November 1937, one of the survey Fieldmen found fairly good numbers of *Locusta* adults in *jowari* fields between Jhimpir and Thano Bulakhan, and about the same time, fairly large numbers were similarly found in *jowari* along the banks of the Hab River near Karachi. On the 22nd November, and subsequent days, quite large numbers of *Locusta* adults were noted in grassy areas situated between Naka Kharrari and Lak Baduk, the southernmost part of the Ambagh Reks, the density of population being estimated to be between ten and twenty thousand per square mile. These reks had been under observation since 1933, and never before had such large numbers of *Locusta* been noticed on them. One of the survey Fieldmen, who had been examining the Hinidan area in the interior of Lasbela State, found on the 15th November a fairly large concentration of *Locusta* adults (density about 20,000 per square mile), in *jowari* fields at Hasan Pir, and he was assured by the cultivators that these locusts had been noticed on the crops only recently. He met with similar concentrations on crops in several other places, also alongside the Sind-Lasbela borders, such as Thana Kila, Hinidan, Koh Mahir, Pabuni, and Goth Sherkhan. Subsequently, fair numbers of *Locusta* were also found in the interior of the Lasbela State, at Uthal, Wahyara, Thana Tappi, Nakhetri, and Liari, and one specimen, as far west as Chandragup. A few stray specimens were also observed in the Ormara and Kulanch areas in November. In December, fair numbers of *Locusta* were found at Meting (Karachi District) on the *jowari* crop.

During a rapid survey tour made in December, 1937, in the Gujarat-Kathiawar areas and again in February, 1938 in the Kathiawar-Cutch areas, small concentrations of *Locusta* adults were noticed in December at Nawanagar and Kuranga along the west coast of Kathiawar, as well as stray specimens of adults and hoppers in parts of Kathiawar. In February, 1938, a few adults were found in the Junagarh area of Kathiawar, and small numbers at Bhuj, Bhachau, Mandvi, etc., in the Cutch State. Locust droppings were also found in wheat fields and grass areas in many localities in Cutch and Kathiawar indicating that locusts had visited them some time ago.

6. Distribution in spring, 1938.—It was noticed that the large numbers of *Locusta* adults found in *jowari* fields in Karachi-Lasbela areas, disappeared after the crop-harvest, and it is presumed that they became scattered over the

area. In February, stray hoppers were seen in many parts of the Lasbela State, and it is surmised that egg-laying had taken place after the fall of good winter rains in December and January last, but few adults were noticeable. No locusts were observed in December in the Kachhi area, whereas during a visit paid to the Kachhi, Bolan and Harnai areas of Upper Baluchistan in March 1938, it was noticed that *Locusta* adults were present there in varying numbers concentrated on the irrigated wheat crop, which was then mostly in ears. As many of the *Locusta* females showed traces of soil and froth on their valves, there is little doubt that they had already laid eggs in the soft, moist loamy soils of the wheat fields. As by the time wheat is harvested, neighbouring fields would have been sown with *jowar* and melons, the hoppers will presumably transfer themselves to the latter on hatching. It is obvious that the large concentrations of hoppers noted last year in June at Kirtha should have been the result of similar concentrated egg-laying in wheat fields in March last. (Large numbers of hoppers have since been reported to have been found at Kirtha in May 1938).

Analysis of the data and inferences

In analysing the data of the past seven years—as detailed above—the following observations may perhaps be made.

1. In the *Sind-Rajputana* area, which is subject to monsoon or summer rainfall, the solitary phase individuals of the Migratory Locust, as in the case of the Desert Locust, are most in evidence during the monsoon months, and are least noticeable during the dry season between January and May. *Locusta* breeds in this region soon after the fall of monsoon rains, and the adults of the new generation generally make their appearance during August or by the beginning of September. If the rainfall continues to be satisfactory in August and September, a second generation may be produced in the desert during October. On the other hand, in the Baluchistan areas, *Locusta* is generally to be seen in the spring months, and breeding may take place in spring or early summer. As the eastern parts of Baluchistan, such as Loralai and Sibi Districts, Lasbela, Jhalawan, and Kachhi, and the Kolwa and Panjgur areas of Mekran, generally come under the influence of the monsoon to a greater or lesser extent, a summer brood of *Locusta* may come into existence in these areas, as in the case of *Schistocerca*. Should there be no rainfall in summer, neither adults nor hoppers of *Locusta* are likely to be found during the summer months in Baluchistan.

2. During the year 1936, the effect of climatic fluctuations on the populations of the Desert Locust was under study during September and October in the desert areas. It was noticed that the populations of *Schistocerca* as well as of *Locusta* rather suddenly disappeared in the southern areas during the latter half of September and the main factors concerned in this phenomenon were found to be a rise of diurnal temperatures, a fall of relative humidity of the atmosphere, and the appearance of dust-storms in the afternoons. It is conjectured that the above-stated changes in the climatic conditions had rendered the environment in the desert uncongenial to the adult locusts and

had caused them to take to flight and leave the area, the time of flight synchronising with that of the occurrence of the storms. On the other hand, by November there was a definite fall in the temperature levels as well as a slight rise in atmospheric humidity due to the advent of the cold weather, and in areas, like that of Nokh in 1936, where locusts had become fledged late in the season, there was no attempt on their part to leave the area. They passed the winter there, and began to disappear only at the end of February 1937, when dry hot conditions again began to prevail.

An emigration of adult locusts was brought about in August-September 1937, when on account of the prolonged break in the monsoon in August 1937, conditions of comparatively high temperatures and low humidity prevailed in the north-eastern areas of the desert, as had happened in September 1936 in the Thar Area.

3. Though various observations made during the period 1931-1935 rather vaguely pointed to the possibility of a shifting of the *Locusta* population from the spring rainfall areas of Baluchistan into the summer rain regions of Rajputana and *vice versa* with the change of the seasons, no definite evidence was forthcoming. During the period 1936-1938, however, owing to the occurrence of heavy as well as extensive breeding of *Locusta* both in spring and summer in different parts of North-West India, fairly definite indications of a transfer of population from one area to another have become available (*vide* map appended). First, fairly good numbers of *Locusta* adults were noticeable in the Jaisalmer area during the months of October-December 1936, but were not to be seen there from January 1937 onwards till June next. Secondly, heavy breeding was noticed in May and June 1937, in the Kachhi area and in the hill-valleys of Baluchistan, such as Bolan and Kohlu, bringing about a high rise in the density of population. By June-July, however, there was a very considerable decrease in numbers here. Thirdly, at about the same time, heavy concentrations of *Locusta* adults made their appearance in the eastern parts of the Indian Desert, as at Reni and Sadulpur. There was extensive breeding in these parts in July-August, but by September the density of population had greatly decreased, evidently by emigration. Fourthly, in September-October an incursion of *Locusta migratoria*, followed by a heavy infestation of cereal crops, had occurred in the Sirohi-Idar-Mehsana areas, and comparatively light breeding in the Thar area ; but during November, the adults produced here were found disappearing. Fifthly, concentrations of *Locusta* adults of varying densities were observed on *jowari* and wheat crops during November-December in the Karachi-Lasbela areas, as also, in parts of Kathiawar and Cutch ; and lastly, very few *Locusta* adults were noticeable in February 1938, in the Karachi-Lasbela areas, whereas, fairly good numbers were seen in wheat crops in March in the Kachhi-Bolan-Harnai areas of Baluchistan.

4. So far, no direct evidence has been obtained in regard to the ability of the solitary phase form of *Locusta* to migrate from place to place. Marking experiments could not, unfortunately, be tried early enough during the year, and out of about sixty specimens marked and released in December 1937, at

Ambagh, none have so far been recovered. As yet, no actually observed cases of high flights have been recorded, except, perhaps, in one rather peculiar instance, in which a *solitaria* individual of *Locusta* was observed, on the 1st August 1937, dropping like a stone from above at about 8 P.M. at night, attracted to the bright light of an incandescent mantle lamp kept in the courtyard of the Nokh Outpost. As the courtyard in question was shut off by fairly tall huts on three sides and was open only to the north-east, and as a strong south-west wind was blowing at the time, it was surmised that the locust had been attracted to the light while migrating high above ground-level with the prevailing wind. On that day, it may be added, neither *Locusta* nor *Schistocerca* was located anywhere in the vicinity of Nokh during survey.

On the other hand, there is strong indirect evidence in regard to the reality of migration. The very fact that in certain cases, large numbers of locusts had often been met with in places where none had been seen a short while ago, and in certain others, few were noticeable in localities where they were known to have been present some time earlier in very large numbers, may be taken as presumptive evidence in regard to their powers of migration. The rather extraordinary sequence of occurrences chronicled last year (1937) (see map attached), *viz.*, the breeding in May-June in Kachhi and Bolan, and then in July-August in east Bikaner, followed by the reported infestation in Sirohi and Gujarat in September-October, and the concentrations observed in crops in Lasbela and Kathiawar in November-December, and in Kachhi-Bolan in March, 1938, would really appear to be an organically linked chain of events, that cannot be explained except on the basis of a hypothesis of a migration flight of individuals from one breeding ground to another under the directive force of the prevailing winds.

5. Although the *solitarias* of both *Locusta* and *Schistocerca* show a good deal of agreement in their general breeding habits and in their reaction to climatic conditions, they present certain striking contrasts in their ecological preferences, which are of importance in a study of the factors that bring about swarming. Whereas the Desert Locust favours comparatively dry situations, prefers sandy areas for egg-laying, and is, on the whole, of cosmopolitan tastes, though usually exhibiting a definite choice for certain wild food-plants, *Locusta* has a preference for relatively more moist micro-climates, generally selects loamy soils for oviposition and has a strong predilection for food plants of the grass family, whether wild or cultivated. In the areas of the Indian Desert, *Locusta* generally lays eggs in clayey hollows in the midst of sand-mounds, and the adults also prefer to concentrate on densely grown crops, such as *bajri*, *jowari*, wheat or millets, or among thick clumps of grasses. In this connection, Faure's remarks [1932] on the habits of *Locusta m. migratorioides* ph. *solitaria* in South Africa are of much interest: " The habits of this locust stand in direct contrast to those of *Locustana pardalina*; the latter is a lover of open spaces, while the former hides in the dense growth of lucerne, and is exceedingly difficult to catch, mainly because it gets down near to the ground and hides. It has been found in greater numbers in weedy (*i.e.*, grassy) fields of lucerne. At Brandvlei, I found this locust in the stubble of recently

cut wheat lands. In De Aar district it was taken in maize lands—small irrigated patches in the semi-arid Karroo—but not in the open veld where *L. pardalina* occurs".

6. The fact that this locust tends to concentrate in patches of cultivated cereals and to lay eggs therein, if the conditions are favourable, is important from the point of view of the formation of incipient swarms. In the Bolan valley, as also in similar other hill-valleys of Baluchistan, arable land is limited to patches of fine silt of varying extent, deposited at the bottom of hollows between rocky, barren hill ranges, and the extent of cultivation of wheat, and later on of *jowari* is dependent on the quantity of spring or stream water available for irrigation. By the time the hoppers emerge from eggs laid in the wheat fields, the crop is ready to be cut, but since the neighbouring fields are generally sown with sorghum and melons, they may feed either on grasses in the harvested fields or transfer themselves to the sorghum plants. There are, thus, great possibilities of concentrated breeding of *Locusta* taking place in the narrow hill valleys of Baluchistan. In the high dune areas of the Indian desert, *bajri* (*Pennisetum typhoideum*) is generally cultivated in the hollows between the sand-ridges, where the soil is comparatively more clayey and moist, for which reason, *Locusta* also selects such areas for egg-laying. If the number of migrating locusts should be large, crowded oviposition might result, but in seasons of good rainfall, the general vegetation, including various grass annuals, springs up in such profusion on the vast expanses of the desert, that the hoppers would tend to get dispersed and isolated amongst the dense vegetation, unless the population is very dense.

Notes on the phase characteristics of the *Locusta* population in 1937

In the course of the year 1937, a collection of *Locusta* adults was made from the different areas where breeding of *Locusta* or the appearance of adult individuals or concentrations had been noticed. These collections were studied by Mr. R. L. Gupta, Biometrical Assistant, attention being concentrated mostly on the determination of the Elytron/Femur ratios, the results of which have been classified in Table IV (Appendix). Zolotarevsky [1933] had, in his studies of *Locusta m. capito*, tentatively fixed the limits for *gregaria* ratios for *Locusta* at 2·00, so that those showing 2·00 or above were to be considered as *gregaria* and those below as *solitaria*. From a study of the *solitaria* specimens collected in India, it would appear that the limit for *solitaria* should be fixed somewhat lower, as most of the measurements lie between 1·80 and 1·90. For the sake of convenience, 1·90 has been taken as an arbitrary upper limit for *solitaria*, and ratios between 1·91 and 2·00 have been classified in this paper as representing '*intermediate*' or *transiens* ratios, and those above 2·00 as *gregaria*.

Of the forms collected in Sibi, Kachhi and Bolan areas in May and June only 14 per cent showed the '*intermediate*' ratios, *i.e.*, E/F ratios of over 1·90. The great majority were all '*solitaria*' in character.

The collection of adults made in June-July in the Jaisalmer area and the forms found in the concentrations found in July in east Bikaner area had a higher proportion of the ' intermediate ' ratios, *viz.*, about 32 per cent.

Among the forms found in Thar-Mallani area in July-August, and in the collections made in the Bikaner-Jaipur-Jodhpur areas in September-October, the proportion of ' intermediate ' ratios was low (6 to 9 per cent), and in the Thar-Mallani area in November, the proportion is higher (25 per cent).

In the areas of infestation in Sirohi, examined on the 31st October 1937, it is interesting to note that 31 per cent of the number of specimens collected showed ' *intermediate* ' ratios, 46 per cent ' *gregaria* ' ratios, and the rest, about 23 per cent, ' *solitaria* ' ratios. In the Mehsana area of infestation, a collection of specimens was made only by the second week of November, at a stage when a great many of the adults of the new generation were reported to have already disappeared ; *gregaria* forms were not found in this population, but about 75 per cent of the specimens collected showed ' *intermediate* ' ratios.

Finally, the concentrations of adults found in sorghum fields in November-December, in the Lasbela—Karachi areas, had about 23 per cent of ' *intermediate* ' forms, the rest being all *solitaria*.

The above results show that, during 1937, the proportion of ' *intermediate* ' to ' *solitaria* ' showed a general tendency to rise with the gradual rise of population. The degree of development of the higher phase ratios would appear to be dependent on the strength of concentration at the breeding period, the *gregaria* forms having appeared this year only at the peak of the breeding.

Specimens of ' *transiens* ' and ' *gregaria* ' forms collected in the Sirohi area were sent to the Imperial Institute of Entomology, London, and the phase determinations were confirmed. Dr. Uvarov, who examined them, stated that in the absence of a larger series of *gregaria* forms, it would be difficult to say which sub-species of *L. migratoria* the Indian forms are to be referred to. He, however, thought that the Indian forms approached the form *manilensis* in their size, though in the shape of the prothorax they approximated *migratorioides*.

Natural enemies observed

The natural enemies observed so far include some of the common bird predators, a bat and two mite parasites.

The birds found attacking this species were : 1. the Indian Roller (*Coracias*), the Bee-eater (*Merops viridis*), the Grey Shrike (*Lanius*), the Mynah (*Acridotheres*), the Drongo (*Dicrurus*) and the Starling (*Pastor roseus*), the last being found occurring in large flights.

In one of the places in the Vijapur Taluka of Mehsana District, a fairly decent heap of cut wings and hind-legs of *Locusta* was discovered at the base

of a large hollow in the trunk of an old *mahua* (*Bassia*) tree in the vicinity of affected fields, indicating that bats had been actively feeding on *Locusta* adults at night.

Of the mite parasites, one was the common red mite found on the wings of various locusts and grasshoppers, possibly the young ones of *Trombidium grandissimum*. The other—possibly a Tarsonemid—is a mite of cream yellow colour, found occurring in masses on the thorax, abdomen and wings of the adult. Eggs, larvæ and adults of the mite generally occur crowded together on the locust, and at times the percentage of infested locusts is very high.

Past records of swarming of *Locusta migratoria* in India

Most of the known records of locust swarms in India refer either to *Schistocerca* or *Patanga*, and there is no definite record of swarms of *Locusta*, although the *solitaria* form of *Locusta* is known to occur throughout India.

There is, however, one striking case of infestation, which Cotes [1891] has recorded referring to it as the Madras Locust Invasion of 1878. According to him, locusts invaded the whole of the Madras Presidency in 1878, the last year of the great South Indian Famine, causing damage high enough to aggravate the distress resulting from the famine. "The young locusts (hoppers) began to appear in January and were found in great numbers in different districts from that date on till September and October—the earliest swarms being found in the south and west of the Presidency and the later ones in the north and east. The winged locusts were first observed in the end of March and the beginning of April in the south-west (Wynaad and Nilgiris), and they afterwards spread over the Presidency to the east and north, not finally disappearing till about November and December. Young locusts (hoppers) which were found in the early part of May in the Udamalpet taluq were supposed to be the offspring of the large flights of winged locusts that had appeared in the preceding February in the same taluq, and it is stated that locusts were observed pairing in the latter part of June in the Salem District (situated towards the north-east)". The visitation was apparently of considerable magnitude, since control measures such as the destruction of large numbers of hoppers by driving them into lines of burning straw, and driving winged locusts from one village to another by beating through the crops, had to be adopted.

Specimens supposed to represent the Madras Locust preserved in the Central Museum, Madras, are said to have included no less than six distinct species of Acrididæ, such as *Cyrtacanthacris*, *Acrida*, etc., of which *Pachytylus cinerascens* (*Locusta migratoria danica*) was the only representative of a real locust.

It may be observed that the months of January, February and March are warm enough, in the parts of South India referred to by Cotes, to favour locust breeding. The prevalent winds in these regions are from north-east to south-west during the period between October and February, and south-west to north-east between May and September, so that the direction of the

locust movements recorded coincide with the wind directions. Though from the data available * there is no definite indication as to the identity of the locust concerned, it appears probable that the species in question was *Locusta migratoria*, and the origin of the infestation was, possibly, derivable from some concentrated breeding that had taken place in grass areas near the foot-hills of the Western Ghats Ranges during the rains of the north-east monsoon.

Possibilities of *Locusta* forming swarms in India

Locusta migratoria ph. *solitaria* appears to resemble the solitary phase of *Schistocerca gregaria* very closely in the broad outlines of its life-history and habits. In both, there is no diapause in the egg-stage ; under natural conditions, oviposition is, in both, dependent on the occurrence of rainfall ; the period of duration of the egg and hopper stages is short whenever conditions of temperature and humidity are favourable ; and in both species, there is the possibility of the occurrence of two or more generations during a year, in case the individuals can reach appropriate rain-belts at the right time. Although the *solitaria* form of *Locusta* is known to occur throughout India, no continuous observations have, as yet, been made as to its annual life-cycle in India, except in the desert areas of north-west India.

It is, however, evident that the possibility of the continuance of an infestation over a series of years of a locust possessing the life-habits of *Schistocerca* or *Locusta* would be dependent solely on its ability to reach suitable areas of rainfall, so as to ensure the development of at least two annual broods in order that its numerical strength might be maintained. In the major part of the Indian continent, rains are confined to the period of the summer monsoon between June and September, and the rest of the year is on the whole comparatively dry. On the other hand, the southern parts of the Indian Peninsula are under the influence of the retreating or north-east monsoon which lasts between October and January. Again, the north-western parts of India, including Baluchistan, North-West Frontier, Punjab, Kashmir and part of the United Provinces, receive varying amounts of winter rainfall distributed in the period between December and March, in the course of the development of a series of western disturbances which originate on the Mediterranean coast and pass eastwards across Iraq and Iran. Both in the case of South India (with the exception of the West Coast) and Baluchistan (excepting the eastern parts), rainfall is comparatively light during the monsoon period.

In north-west India, the occurrence of a spring brood in Baluchistan, followed by a summer brood in the Rajputana desert area, is rendered possible by the differences in the time of occurrence of rainfall in these regions and the active part taken by the seasonal winds in the transfer of the locust population from one region to the other during summer and autumn. On the other

* Through the courtesy of the Development Department of the Government of Madras, the Proceedings of the Board of Revenue, Madras for 1878, containing the accounts of the 1878 infestation, have since been studied, from which it has now become fairly evident that the species concerned was *Locusta migratoria*.

hand, the winter rain area of South India would appear to be cut off from the breeding areas in the desert not only by the great distance but also by the lack of favourable wind agency. If, for example, the seasonal winds during November, 1937, had been such as to transport the high population of *Locusta* produced in the Sirohi-Mehsana areas, into the north-east monsoon areas of Madras, there should have been the danger of a serious infestation developing in South India.

Even in the Baluchistan areas, winter rainfall is late and generally scanty, and at any rate, owing to the temperature conditions of winter, breeding would not be possible in the hill-valleys of Baluchistan till March-April. Should there be heavy spring rainfall in Baluchistan, followed by concentrated breeding, and should there be two successive generations in the monsoon areas, as had happened in 1937, there might be a danger of swarming of *Locusta* in India, but in the present state of our knowledge, it is not possible to make any statement as to whether the swarms of *Locusta*, when once they are started, would be able to continue their activity in the rest of India, on the analogy of the behavior of *Locusta m. migratorioides* in Africa.

Significance of the phenomenon of migration among the *solitaria* locust population

The significance of the powers of migration shown this year by the *solitaria* population of *Locusta migratoria* in north-west India cannot be over-estimated, especially with reference to the formation of incipient swarms. For instance, during the investigation of the serious infestations reported from the Sirohi and Mehsana areas in 1937, the outbreaks should have had to be considered as having been of purely local origin, if the facts in regard to intensive breeding in the Baluchistan and Bikaner areas had not been known. Similarly, the disappearance of the forms of the new generation should have otherwise been attributed to the action of natural causes, such as the activities of natural enemies. With the fairly definite circumstantial evidence obtained now in regard to the migration of the *solitaria* individuals, we have now clues of value to determine whether breeding of any considerable magnitude could be expected at any particular time in north-west India.

Though it is risky to hazard any statement with reference to regions of which one has no personal acquaintance, the senior author of this paper is inclined to believe that it is not very unlikely that the solitaries of other races of *Locusta migratoria* in Africa, Europe and China may also be found to have similar habits of migration.

In regard to the study of the factors which contributed to the development of the primary outbreak centre of *Locusta m. migratorioides* R. and F. in the current outbreak in Africa, which has achieved a phenomenal spread covering over ten million square miles, the senior writer of this paper would venture to make a few observations. The very interesting analysis made by Lean [1931] in regard to the movements of the early swarms of *Locusta m. migratorioides* in the regions of West Africa during the period 1928—1930

would indicate that the movements have been, in general, north-east to south-west in the autumn and south-west to north-east in early summer, coincident with the prevailing direction of the seasonal winds of the period. Breeding would appear to have occurred on the west coast in Senegal, French or Portuguese Guinea in April after the early rains; and the new generation of locusts would appear to have moved eastwards in June-July into the Niger area, where breeding would seem also to have taken place thereafter. In autumn the swarms of the new generation would appear to have been moving westwards once again. It was only in 1930, between May and July, that a considerable part of the swarms moved further east into Anglo-Egyptian Sudan, from which area the succeeding generation flew southwards, thus marking the commencement of the main invasion of the central parts of the African Continent. It may be noted here, however, that in spite of the great developments in the central and southern regions of Africa during the period 1931 to 1936, West Africa has continued to be subject to the periodical invasions of swarms, the direction of movements of which would appear to have varied more or less directly with the trend of the prevailing winds at the change of the seasons [Uvarov, 1933; 1934; 1935; 1936]. Observations on the occurrence of seasonal migrations of *solitaria* individuals of *Locusta migratoria* in this important area would be of particular interest.

Summary

1. In the course of periodical surveys carried out since 1931 in the desert areas of Sind, Baluchistan and Rajputana, in connection with the observations on the seasonal distribution of the solitary phase of the Desert Locust, stray specimens of the solitary phase of the Bombay Locust (*Patanga succincta*) and the Migratory Locust (*Locusta migratoria*) were being found, and in view of the evidence obtained in 1935 as to the capability of the *solitaria* individuals of the Desert Locust of making long, seasonal migrations from winter-rain areas to summer-rainfall areas in early summer, and back again in autumn, all the data gathered during the past seven years in regard to the Migratory and Bombay Locusts were collected together and studied.

2. In the case of the Bombay Locust, it may be stated that most of the forms were met with in the areas of Rajputana, Sind and Western India States, and always either in autumn, winter or spring months, but never during the monsoon period. Though it is evident that the forms met with are migrants, the data available at present are not such as to lead to any definite conclusions.

3. In regard to the Migratory Locust, the data for 1931 to 1935 are rather fragmentary, but serve to indicate though vaguely that the *Locusta* population is most in evidence in the desert areas during the monsoon months, during which period breeding also takes place. In the Baluchistan areas *Locusta* is observable mostly in spring, when it breeds there generally. In case there should be summer rainfall, summer breeding also may occur.

4. The data for 1936-38 are very much fuller, and detailed observations are available. During May-June, 1937, there was intensive multiplication in the Kachhi, Bolan, and Kohlu areas of Baluchistan, but by August, the high population noticed in June had disappeared. In July, rather dense concentrations of *Locusta* adults were seen in east Bikaner and there was heavy multiplication in July-August there. Owing to the development of a drought in August, the population gradually disappeared during September. In September-October, there was a severe hopper infestation in millets in the Sirohi-Mehsana-Idar areas, which is presumed to have developed from locusts derived from the Bikaner areas. In November-December, large concentrations of adults were found in *jowari* fields in Kathiawar, Sind and Lasbela ; and in March 1938, none were to be found in Sind and Lasbela, though a fair number was seen in wheat fields in the Bolan Valley. From the above it is obvious that there has been a great shifting of population from one area to another during 1937, leading to considerable infestation.

5. Though no direct evidence in regard to migration has been available, there is much circumstantial evidence to show that the *solitaries* of *Locusta* are capable of long distance migration, like those of the Desert Locust. The sequence of events recorded in 1937, *viz.* the successive broods noted in May-June, July-August and September-November, and the concentrations of adults noted in *jowari* in November-December, and in wheat in March 1938, is a fairly clear indication of the migratory capacities of *Locusta*.

6. *Locusta* differs from *Schistocerca* in its ecological preferences, as it definitely favours a fairly moist environment, and has a special predilection for food-plants of the grass family. These preferences are of special significance, as they lead to the formation of its concentrations on irrigated crops like wheat and millets in hill valleys, and to the development of outbreak centres in such situations as a result of crowded breeding.

7. A study of the phase characters of the populations collected during different parts of the year 1937 has shown that the insect had undergone a certain degree of morphological change as a result of crowded breeding. In general the proportion of forms with '*intermediate*' E F ratios as compared with the *solitaria* ones showed a definite rise and in one case (at Sirohi), definite '*gregaria*' ratios were found to have been developed.

8. The natural enemies observed consisted of the usual bird predators, certain bats and two kinds of Acarid mites.

9. Although the *solitaria* form of *Locusta migratoria* is common throughout India, there are no definite records of the development of swarms of *Locusta* in India, but a case recorded by Cotes in the *Indian Museum Notes* Vol. 2 (1891—1893) under the title "Madras Locust Invasion of 1878" may possibly have been an instance of the swarming of this species.

10. The development of an infestation of locusts of the type of *Locusta* or *Schistocerca* is dependent on the existence of a combination of suitably situated summer and winter breeding grounds between which the seasonal winds can naturally bring about a regular transference of locust populations

at the end of the breeding period, rendering it possible for the locust to have both a summer and a winter or spring generation during the year. A serious infestation can, however, develop only in case the locust is able to greatly multiply in numbers as a result of two or more consecutive broods developing with the occurrence of exceptionally high rainfall in winter as well as in summer. It is, therefore, considered that the swarming of *Locusta* would, under the conditions of north-west India, be a rather exceptional event.

Acknowledgments

The authors take this opportunity of thanking the various authorities in Sind, Punjab and Baluchistan and the Western India States Agency, and the State Authorities in Kalat, Lasbela, Bikaner, Jodhpur, Jaisalmer, Jaipur, Sirohi, Idar, Palanpur, Baroda, the Kathiawar States, and Cutch for the help received in the course of the investigation. The senior author wishes specially to acknowledge the help received from Dr. V. N. Likhite in investigating the infestation in the Mehsana District. He is much indebted to Dr. H. S. Pruthi, Imperial Entomologist, New Delhi, for permission to examine the locust specimens in his collections. The authors wish to express their thanks to Sir Guy Marshall, Director, Imperial Institute of Entomology, London, for the determination of specimens sent, and, last but not least, to Dr. B. P. Uvarov for much help and advice.

REFERENCES

Cotes, E. C. (1891). *Ind. Mus. Notes* **2**, 101—103

Kirby, W. F. (1914). Fauna of British India, Orthoptera (Acridiidae)

Lean, O. B.(1931). *Bull. Ent. Res.* **22**, Part III

Lefroy, H. M. (1906). *Mem. Dept. Agric. Ind.* (*Ent. Ser.*) **1**, No. 1

Rao, Y. R.(1936). *Ind. J. Agric. Sci.* **6**, 1031

———— (1937). *Proc. Fourth Internat. Locust Conf.* (*Cairo*) April 22, 1936, Appendix 10

Uvarov, B. P. (1928). " Locusts and Grasshoppers ", Imperial Bureau of Entomology, London

———— (1933). " Locust Outbreak in Africa and Western Asia, 1925-31 "; "Locust Outbreak in Africa and Western Asia in 1932 " : Econ. Adv. Council, Committee on Locust Control

———— (1934). " Locust Outbreak in Africa and Western Asia in 1933 " : Econ. Adv. Coun., Committee on Locust Control

———— (1935). " Locust Outbreak in Africa and Western Asia in 1934 " : Econ. Adv. Coun., Committee on Locust Control.

Uvarov, B. P. and Milnthorpe, W. (1936). " Locust Outbreak in Africa and Western Asia in 1935 " : Econ. Adv. Coun., Committee on Locust Control

———— (1937). " Locust Outbreak in Africa and Western Asia in 1936 " : Econ. Adv. Coun., Committee on Locust Control

Zolotarevsky, B. N. (1929). *Annales des Epiphyties* **15-e**, No. 4

———— (1933). *Annales des Epiphyties* **19-e**, Nos. 1 & 2

Appendix

TABLE I

Finds of Solitaria *specimens of the Bombay Locust* (Patanga succincta) *in the desert areas of North-West India during 1933—1938*

Year	Season	Month	Baluchistan area	Sind-Rajputana-Kathiawar areas	No. of specimens found
1933	Spring	March	*Nil*	Radhanpur (4th March 1933)	One specimens
				Cutch (11th March 1937)	Four specimen
1934	Spring	May	*Nil*	Cutch (4th May 1934)	Two specimens
	Autumn	November	...	Bikaner (Sardarshahr) (4th November 1934)	One specimen
1935	Winter	January-February	*Nil*	Thar-Mallani area—	
				(Virawah, 27th January 1935)	Two specimens
				(Harrah, 30th January 1935)	One specimen
				(Dhorimana, 12th February 1935)	One specimen
	Summer	June	*Nil*	Jaisalmer (Nokh, 4th June 1935)	One specimen
1936	Autumn-Winter	November-December	*Nil*	Bikaner (Sonpalsar, 7th November 1936)	One specimen
				Jaisalmer—	
				(Girasar, 20th November 1936)	Two specimens
				(Nokh, 12th December 1936)	One specimen
1937	Winter	January	*Nil*	Jaisalmer— (Tarana, 18th January 1937)	One specimen
		February	*Nil*	(Nokh, February 1937)	Seven specimens
				(Lathi area, February 1937)	Five specimens
	Spring	March	*Nil*	Bahawalpore (Mithra, 9th March 1937)	One specimen
		April	...	Jaisalmer (Baru, 11th April 1937)	One specimen
	Autumn	October	*Nil*	Bikaner (Bambu, 27th October 1937)	One specimen
		November	...	Mallani (Barmer, 27th November 1937)	One specimen
	Winter	December	...	Bikaner (Sardarshahr, 10th December 1937)	One specimen
				Mallani area (Nand, 28th December 1937)	One specimen
				Kathiawar (Amreli, 26th December 1937)	One specimen
1938	Winter	January-February	*Nil*	Jaisalmer (Nokh, 14th January 1938)	One specimen
				Bikaner (Sardarshahr, February 1938)	Three specimens
				Thar area (Virawah, 8th February 1938)	One specimen
				Kathiawar—	
				(Junagarh, 12th February 1938)	One specimen
				(Viramgam, 2nd February 1938)	Two specimens
	Spring	March	Kachhi (Dadhar, 23rd March 1938) 1 specimen	Bikaner (Sardarshahr, 6th March 1938)	Two specimens

TABLE II

Available data regarding the occurrence of Locusta migratoria *for the years 1931—1938 in the Baluchistan and Sind-Rajputana Desert areas of North-West India*

Year	Season	Baluchistan Region				Sind-Rajputana Region			
		Area	Month	Particulars	Rainfall	Area	Month	Particulars	Rainfall
1931	Spring	Mekran	April	Adults (Pasni, Ormara) 4 specimens	Fairly good	No data available			
			May	Adults and a few hoppers (Panjgur) 2 specimens					
	Summer-Autumn	Harnai	July	Adults (Shahrig) 10 specimens	Fair	No data available			
		Kachhi-Sibi	August	Adults (Jhatpat) 1 specimen					
1932	Winter-Spring	Mekran	April	1 specimen (Pasni)	Failure	No data available			
		Upper Baluchistan	April	Adults (Quetta) 2 specimens	Winter rain below normal				
	Summer-Autumn	Mekran (Kolwa)	September	Adults and a few hoppers (Kolwa)	Good rain in July	Bahawalpore State	November	Adult (Khairpur) 1 specimen	Good falls
						Jaisalmer State	November	A few adults (Sodakhor)	
1933	Winter-Spring	Mekran	April	Adults (Pasni) 2 specimens	Good rains	West Sind	February	Adults (Akil) 2 specimens	Fair
							May	Adults (Akil) 4 specimens	
						Bahawalpore State	June	Adults (Fort Abbas) 1 specimen	

TABLE II—*contd.*

Year	Season	Baluchistan Region				Sind-Rajputana Region			
		Area	Month	Particulars	Rainfall	Area	Month	Particulars	Rainfall
1933	Summer	Lasbela	July-Aug.	Adults 3 specimens	Good rain	West Sind	July	Adults (Shah Hasan) 3 specimens	Heavy rainfall
		Mekran	July	Adults (Panjgur area) 8 specimens		Bikaner	July	Adults (Nohar) 4 specimens	
			August-September	Adults (Kolwa area) 5 specimens		Bahawalpur-Bhatinda	August-September	Adults specimens	
		Kachhi	August	Adults (Chattr) 1 specimen					
	Autumn	Mekran	September-October	Adults (Kech, Kalmalt) 5 specimens	...	Sind (Khairpur)	October	Adults (Thari) 3 specimens	Good rain in September-October in desert
			November	Adults (Kech-Panjgur area) 6 specimens		Derajat	October-November	Adults (Mithankot Parao) 4 specimens	
			December	Adults (Buleda) 1 specimen		Sind (Thar area)	October	Adults (Chachro) 4 specimens	
						Jaisalmer	October-November-December	Adults (Baru, etc.) 8 specimens	
						Bahawalpur	December	Adults (Fort Abbas, Ft. Marot) 10 specimens	
						United Provinces (Muttra Distt.)	November	Adults 1 specimen	
1934	Winter-Spring	Mekran-Baluchistan	May	One adult (Panjgur) No other record of specimens anywhere in Mekran and Upper Baluchistan	Complete failure of Winter rains	West Sind	April	Adults, a few (Mirzapur) 1 specimen	
						Cutch State	May	Adults (Mandvi) 2 specimens	
						Bikaner	May	Adults (Suratgarh etc.) 6 specimens	
						Bahawalpur	May	Adults (Shahwala) 1 specimen	

	Summer-Autumn	Mekran .	July .	One specimen was collected at Pasni	No rain in Mekran	Sind (Thar area)	June-July .	Numerous adults (Chachro, Rahimki-Bazaar) 13 specimens	Monsoon began early in second half of June Rains light in August-September
		Lasbela .	November	One adult at Hingol	Light fall in Lasbela		August . .	Hoppers (Chachro) Adults (Diplo, etc.)	
						Punjab (Ludhiana)	July . .	Adults and hoppers reported from Ludhiana-Patiala area	
						Jaipur State .	September .	Adults (Sikar) 1 specimen	
						Sind (Thar) .	September .	Adults (Saro) 1 specimen	
						Bikaner area .	October . .	A few adults	
1935	Spring .	Mekran .	May .	One specimen collected at Mand	Good rainfall in winter	Bikaner . .	March . .	One specimen at Sardarshahr	...
	Summer .	Lasbela .	June .	One adult at Liari .	No rain in summer	Jaisalmer .	July . .	One specimen at Nokh	Fair
1936	Winter-Spring	...	No record	.....	Fair	.....		No record	
	Summer-Autumn	Kachhi .	July .	Fairly large numbers of adults were found in *jowari* cultivation in the Bhag-Gandhawa areas	No rain in Mekran	Bikaner area .	June . .	An adult (Udasar) .	Monsoon rather light
						West Sind .	July . .	Adults found in fair numbers at Johi in *jowari* fields	
		Lasbela .	November	One specimen collected at Goth Sherkhan	Light rainfall in Lasbela	Bikaner area .	August, September and October	Fair numbers met with during surveys along with the Desert Locust	Very heavy rainfall in East Jaisalmer and Bikaner areas in August 1936
						Jaisalmer areas	October, November and December	Found in good numbers with *Schistocerca* especially in November	
						Thar-Mallani area	August, September, October-November	Found along with *Schistocerca* in fair numbers ; none were noticeable in this area	

TABLE II—*contd.*

Year.	Season	Baluchistan Region				Sind-Rajputana Region			
		Area	Month	Particulars	Rainfall	Area	Month	Particulars	Rainfall
1937	Winter-Spring	Kachhi .	May-June	Adults and hoppers in fairly good numbers	Good spring rainfall in Upper Baluchistan	Thar-Mallani Desert areas	January to June	None found . .	Good falls in February
		Bolan Valley	June .	Very large numbers of hoppers and adults at Kirta		Bikaner-Jaisalmer, Bikaner Desert areas	January to May	Three specimens, observed in east Jaisalmer area, one in February, one in April and one in May	
		Mekran (Kolwa)	May .	Adults found in cultivation					
		Sibi Distt. (Kohlu)	May-June	Hoppers and adults reported		West Sind .	June . .	One adult at Johi	
		Chagai .	June .	A few adults found .		...	...	.....	...
		Lasbela .	June .	A few adults found .		...	...	.....	...
	Summer-Autumn	Kachhi and Bolan	August .	A small number of adults noted	...	Jaisalmer-west Bikaner	July	Present in fair numbers at the beginning of July, but few seen after the 25th	Light falls in July ; *nil* in August Light in September
		Harnai Valley	August .	Hoppers met with in fair numbers, as also some adults		...	August . .	Small numbers noted at the end of August	
						East and Central Bikaner area	July-August .	Enormous numbers of adults were found in certain parts, *e.g.*, Sadulpur ; there was also extensive breeding ; by end of August, large numbers of adults were noted in fields of *bajri*	Heavy rains in July ; none in August ; fair in September
							September .	Only small numbers of adults noticeable	
						Thar-Mallani area	July-August .	Both adults and hoppers found in fair numbers throughout the area	Fair rain in July ; *nil* in August ; good in September

						Sirohi; Gujarat (Mehsana) Kathiawar	September . October-November	Enormous numbers of hopper were found doing damage to *jowari* crops in Mehsana, Idar and Sirohi areas in October; by end of November, most of the adults had disappeared	Good rain in July, *nil* in August, heavy in September
							September-October-November	Adults found in fair numbers; a second brood of hoppers occurred in October-November	
							December .	Most of the adults had disappeared	
	Winter	Lasbela-Karachi	November-December	Great numbers of adult locusts were noticed among *jowari* crops in many places	...	Kathiawar .	November-December	Small groups of adult locusts were found in a few localities in Kathiawar	...
1938	Winter-Spring	Lasbela .	February-March	Small numbers of hoppers were noticed in a few places	...	Cutch area .	January . .	Small numbers of adults in parts of the State	
	Spring .	Kachhi-Bolan-Harnai	March .	Small numbers of adults were found among wheat cultivation in several localities (egg-laying probable)	No spring rains in February and March	...	...	.....	...

TABLE III

Rainfall for the year 1936-37 (in inches)

Month	Panjgur	Turbat	Bela	Ambagh	Karachi	Gandhawa	Bhag	Harnai	Chachro	Barmer	Nokh	Sardar Shahr	Sadulpur	Churu	Mandar	Bikaner	Mehsana
1936																	
December .	0·26	1·05	3·33	2·13	0·10	1·48	0·85	6·39	*Nil*	*Nil*	*Nil*	0·02	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
1937																	
January . .	0·54	0·50	*Nil*	*Nil*	*Nil*	0·10	0·20	0·56	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
February .	1·60	1·20	1·46	0·92	1·00	1·34	1·00	1·38	0·29	0·61	2·22	1·46	1·53	0·65	*Nil*	2·10	0·15
March . .	0·18	0·22	0·70	*Nil*	*Nil*	0·90	0·21	1·29	*Nil*	*Nil*	0·03	0·18	0·15	*Nil*	*Nil*	*Nil*	*Nil*
April . .	0·29	0·34	*Nil*	*Nil*	*Nil*	0·96	0·26	0·87	*Nil*	*Nil*	0·02	0·04	0·04	0·21	*Nil*	*Nil*	*Nil*
May . .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	0·05	*Nil*	*Nil*	*Nil*	0·09	*Nil*	0·28	*Nil*	*Nil*	*Nil*
June . .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	0·94	0·17	0·20	0·03	0·18	1·42	1·21	5·68	*Nil*	13·66
July . .	0·20	0·03	4·07	3·09	8·20	3·15	1·43	6·36	5·86	7·54	2·77	4·00	8·26	7·59	10·99	8·80	17·67
August . .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	0·87	*Nil*	*Nil*	*Nil*	0·29	1·07	0·13	*Nil*	*Nil*	0·33
September .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	2·13	2·63	1·36	1·91	2·01	2·54	2·24	10·13	0·90	15·70
October . .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	0·63	*Nil*	*Nil*	*Nil*	0·02	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
November .	*Nil*	*Nil*	0·03	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
Total .	3·07	3·07	9·59	6·14	9·30	7·93	3·95	21·47	8·95	9·71	6·98	8·29	15·01	12·31	26·80	11·80	47·51

TABLE IV

Results of a biometrical analysis of Locusta *populations in North-West India in 1937*

Serial No.	Months	Area	Total No. examined	'*Solitaria*' ratios 1·90 and below	'*Intermediate*' ratios between 1·91 and 2·00	'*Gregaria*' ratios 2·01 and above
1	May-June . .	Sibi-Bolan-Kachhi areas	35	30	5 (14 per cent)	*Nil*
2	July	Nokh-Jaisalmer-Bikaner areas	43	20	14 (32 per cent)	*Nil*
3	July-August . .	Thar-Mallani area .	21	19	2 (9 per cent)	*Nil*
4	September-October .	Bikaner-Jaipur-Jodhpur areas	37	35	2 (6 per cent)	*Nil*
5	October . . .	Sirohi area . .	26	6 (23 per cent)	8 (31 per cent)	12 (46 per cent)
6	November . .	Thar-Mallani . .	8	6	2 (25 per cent)	*Nil*
7	November . .	Mehsana (Baroda District)	28	7	21 (75 per cent)	*Nil*
8	November-December .	Lasbela area . .	65	50	15 (23 per cent)	*Nil*

ECONOMICS OF FIELD-SCALE SPRAYING AGAINST THE WHITE-FLY OF COTTON (*BEMISIA GOSSYPIPERDA* M. & L.)

BY

M. AFZAL HUSAIN, M.A. (CANTAB.)
KIDAR NATH TREHAN, M.Sc.

AND

PIARE MOHAN VERMA, M.Sc.
Entomological Laboratory, Punjab Agricultural College, Lyallpur

(Received for publication on 22nd February 1938)

(With one text-figure)

CONTENTS

	Page
I. Introductory	109
II. Experimental technique	110
III. Insecticides used	111
IV. Spraying equipment employed	112
V. Efficacy of machinery—	
1. Daily output of work	113
2. Time factor	114
3. Mortality of the pest	114
4 .Consumption of insecticide	116
5. Labour charges, fuel and petrol expenses	116
VI. Efficacy of insecticides	116
VII. Total cost of spraying	117
VIII. Yield tests	119
IX. Summary	126

I. Introductory

The White-fly, *Bemisia gossypiperda* M. & L., is one of the major pests of cottons in the Punjab. It sucks sap from the leaves and drains the plant food. The honey-dew, which it secretes falls on the leaves and serves as a medium for the growth of black moulds, which interfere in photosynthesis. An attack of this pest is, therefore, capable of causing very heavy reduction in yield.

Small scale* experiments, conducted from 1929 to 1932, amply proved the value of spraying for the control of White-fly. In order to estimate the efficacy and economics of this method of control, on field scale, the Indian Central Cotton Committee sanctioned a sum of Rs. 11,250 for spraying trials during 1933. Extensive spraying operations were conducted during July and August, at the British Cotton Growing Association's Farm at Khanewal, and at the Military Farm, Okara. During 1934, the Committee sanctioned another grant of Rs. 6,590, which included a sum of Rs. 5,354 being the amount of savings from the previous year, for further spraying trials. The Committee desired that these trials be extended to four centres, namely Khanewal, Okara, Sargodha and Lyallpur, and that both the *desi* and American cottons be treated and that insecticides other than Rosin compound be tested. It is regretted that the operations could not be carried out at Lyallpur for want of spraying machines.

As far as we know, it is the first time that under Indian conditions, spraying operations have been conducted on so large a scale, in the field. The data presented, therefore, will be useful not only to cotton growers, but also to farmers in general.

The British Cotton Growing Association, Ltd., Khanewal, very kindly placed, at our disposal, their spraying machine (Sapom) free of charge. The Department of Agriculture lent the services of their mechanic and permitted the use of their Orchard Power sprayer and other equipment. One Hardie and one Sapom sprayer were purchased from the grant sanctioned by the Indian Central Cotton Committee during 1933. The generosity of the Committee is gratefully acknowledged.

The statistical analysis of the data was carried out by Mr. B. R. Sehgal, Statistical Assistant, Cotton Research Laboratory, Lyallpur. His help is gratefully acknowledged.

II. Experimental technique

The efficacy of spraying may be determined by comparing the yield from the sprayed fields with that from the unsprayed plots, and also by the actual determination of the percentage of insect mortality. The first method appeals to the grower as it enables him to determine his net gain. This method, however, has serious limitations. The yield of a crop depends upon a number of factors, such as climate, soil fertility, crop rotations, dates of sowing, frequency and quantity of rainfall and irrigation facilities and upon attacks of pests and diseases other than the one under investigation. It is impossible to expect any one of the above factors to be uniform, when one is dealing with large areas at different places. If one could vary the 'White-fly' factor alone, it would be possible to arrive at some definite conclusion, but often unexpected factors come in and vitiate the results of such experiments. For instance, during 1933, some of the sprayed fields

* The average size of plots in these experiments varied from 1/12th to 1/20th of an acre.

at Khanewal were so badly attacked by *Sylepta derrogata*, that the increase in yield as the result of spraying could not be definitely determined. Nevertheless, the data of yields from sprayed and unsprayed fields for the years 1933 and 1934 have been collected and given in Tables IV, V and VI.

The second method gives reliable data of insect mortality, but does not give any idea of the economic advantages of the operation. We have mostly depended upon this method to determine the efficacy of spraying. Mortality among the adults was estimated by counting the dead and living insects soon after spraying. For nymphs and pupae, samples of sprayed leaves were examined under a magnifying lens twenty-four hours after the operation. The natural insect mortality was determined by examination of similar samples of leaves from the neighbouring unsprayed plots.

III. Insecticides used

During 1933, 1280 acres of cotton crop at Khanewal and 521 acres at Okara, and in 1934, 1585 acres at Khanewal, 656 acres at Okara and 45 acres at Sargodha, were sprayed with rosin compound. The other insecticides used are listed below :—

Table I

Insecticides tried during 1933 and 1934

Insecticide	Formula adopted		Dilution tried
Rosin compound	(*a*) Rosin Grade III	5 lbs.	1 : 6
	Washing soda	1 lb.	
	Water	5 gls.	
	(*b*) Rosin Grade III	5½ lbs.	1 : 6
	Washing soda	1 lb.	
	Water	5½ gls.	
	(Used at Khanewal in 1934).		
Rosin soap	Rosin soap	2 lbs.	1 : 8
	Water	1 gl.	
Fish oil soap	Fish oil soap	2 lbs.	1 : 8
	Water	1 gl.	
Tobacco decoction	Tobacco	1 lb.	1 : 6
	Washing soap	½ lb.	
	Water	2 gls.	
Kerosene oil emulsion	Kerosene oil	½ gl.	1 : 9
	Washing soap	2 lbs.	
	Water	2 gls.	
Lime sulphur	Sulphur	5 lbs.	1 : 8
	Slaked lime	2 lbs.	
	Water	4 gls.	

Preliminary dusting trials were also carried out at Khanewal with calcium cyanide and nicotine sulphate during 1933, on an area of ten acres. In 1934, a number of proprietory dusts were tried at Khanewal on an area of twenty-three acres. The heavy cost, coupled with low mortality obtained from these dusts, did not encourage their further use.

IV. Spraying equipment employed

A cart sprayer can only be used when the crop is young and has been sown in lines, but when it has grown tall and is not sown in lines, it is practically impossible to take a machine through the field. To meet these two conditions, we tried two distinct types of spraying machines. The cart sprayers were represented by Hardie and Sapom sprayers, while the Orchard Power sprayer represented the second type. The following is a brief description of various machines and spraying equipment employed.

Cart sprayers

1. Sapom sprayer (cost Rs. 900 to Rs. 1,200).—In this machine the insecticide is forced out of five to seven nozzles, by a pair of pumps which work by means of a gear connected with the wheels of the cart. The force of the spray depends directly upon the speed with which the cart is moving. As the slow motion of the bullocks was not enough to produce the pressure required for a proper spray, the number of nozzles (at Khanewal) was reduced to 5 and they were worked by hand. Thus five boys were employed to work with 5 nozzles, each spraying one row of cotton. At Okara, four boys were employed to work with seven nozzles. Three boys sprayed with two nozzles each, while the fourth worked with a single nozzle. Spraying with two nozzles to a row gave better kill than with one nozzle to a row, although comparatively larger quantity of insecticide was used. The machine is useful, when the crop is not very bushy and trained labour is available.

2. Hardie Power sprayer (cost Rs. 1,100).—This machine consists of a 2 H. P. engine which pumps the insecticide through twelve nozzles, which spray four rows of cotton at a time. The sprayer works exceedingly well, as the nozzles are adjustable and automatic spraying very satisfactory. With a pressure of 75-130 lbs., it was possible to produce a very thorough cloud and spray almost all the leaves of a plant.

3. Orchard Power sprayer (cost Rs. 6,766).—This machine consists of a 36 H. P. engine and is designed to spray tall trees. We tried to adopt it for spraying a crop, when it had grown so tall and thick that a cart could not be taken in and it had to be sprayed from an engine stationed outside the field. The spraying outfit consisted of (*a*) delivery hose about 40 feet long (1 in. diameter), (*b*) a number of light steel pipes each 15 feet long (1 in. or $\frac{3}{4}$ in. diameter), (*c*) flexible armoured rubber joints with gunmetal screw couplings, which allowed the piping being laid on the roughest ground, (*d*) three-way cocks inserted at desired intervals, to the outlets of which were attached, (*e*) flexible

armoured hoses each 70 feet long and (*f*) specially designed horizontal spraying rods, with six nozzles. In Fig. 1, the distribution of pipes and hoses as laid in a cotton field and the rows of cotton sprayed by each rod are shown. One man, worked with one rod and sprayed three complete rows at a time. The rods were kept lifted up by means of a specially designed harness. To avoid any damage to the crop, by dragging the hoses, one additional man was employed at each hose to keep it lifted up.

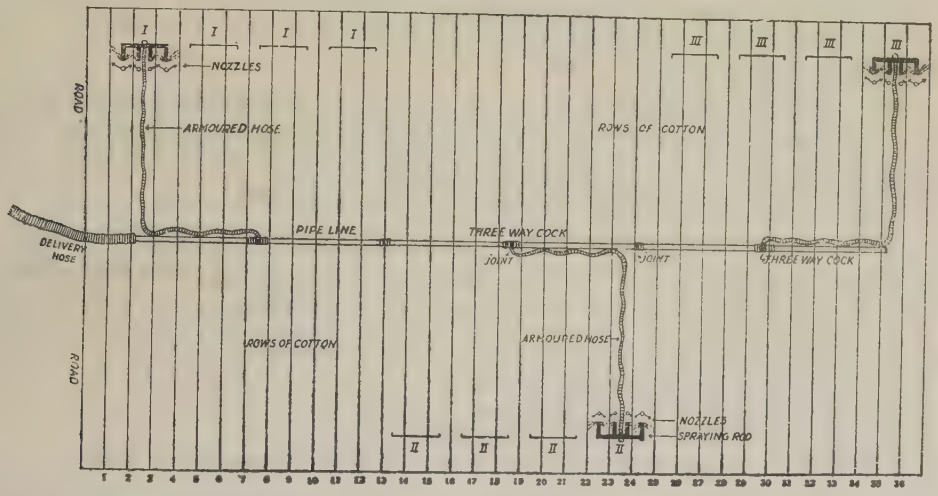


Fig. 1. Distribution of spraying outfit in a cotton field with orchard power sprays

Although spraying with this machine was very satisfactory, thorough and effective, yet its working was very cumbersome. Because of its heavy weight, it was difficult to move the machine from place to place, particularly when the tank was full and the field soft or wet. Further, the laying out of the pipes and their shifting was slow and troublesome. Leakage generally occurred at various joints and considerable time was lost in tightening these. Because of the heavy petrol consumption, and the necessity of employing two mechanics, spraying with this machine proved very expensive.

V. Efficacy of machinery

The efficiency of various machines used in these trials was determined by studying the following points :—

1. Daily output of work.—The daily output of a machine mainly depends on its satisfactory working, speed of bullocks, efficiency of labour employed and the stage of the growth of the crop. At Khanewal (1933 and 1934), two pairs of bullocks were employed for each machine, on a contract to spray 15 acres a day. This arrangement proved satisfactory, as the deficiency on any day was made good subsequently. At Okara (1933 and 1934) and Sargodha (1934) bullock labour was engaged on daily basis.

During 1933, at Khanewal, each machine (Hardie and Sapom) sprayed on an average 15 acres a day. At Okara, however, because of the comparatively thicker crop, the average daily output with the Orchard Power sprayer was only 9·5 acres and with the Sapom 9·9 acres.

During 1934, an extra pair of bullocks was employed at Khanewal, during July, for a period of seven days and this raised the daily output of Hardie and Sapom to 16 acres. At Okara, the average area covered by the Orchard Power sprayer each day was 10·5 acres. This increase was on account of new hoses and pipe connections, which reduced leakage. The average daily output of Sapom was 19 acres.

2. Time factor.—The efficiency of a machine can be further judged by the time lost during working hours, in such operations as filling the tank, cleaning nozzles, and shifting the sprayer from field to field. During 1934, the loss of time with individual machines was as follows :—

The average time required for spraying one acre of cotton crop at Khanewal was twenty-four minutes with Sapom and twenty-six minutes with Hardie. Of this period, nineteen minutes were spent in actual spraying and the rest in filling the tanks, etc. It was calculated that the total time lost each day, in charging the tanks, shifting, cleaning, etc., was 36·4 per cent in the case of Hardie and 33·1 per cent in the case of Sapom.

At Okara, the actual time taken in spraying one acre with Sapom was thirteen minutes and with the Orchard Power sprayer 12·4 minutes. It was estimated from these figures, that 54·2 per cent of the time was lost in the case of Sapom and 75·4 per cent in the case of Orchard Power sprayer, in making preparation for spraying. The increased loss of time at this place in the case of Sapom, was due to the fact that often water had to be carried from a distance and also because the labour engaged on this machine was used in lifting the pipe line, while shifting the Orchard Power sprayer.

3. Mortality of the pest.—In young cotton crop, all the machines proved equally effective in killing the pest, but with the growth of the crop, only the power sprayers yielded satisfactory results. The Orchard Power sprayer was found to be most efficacious because of its good, steady pressure and controlled spraying of the bushes. With Rosin compound, 95·7 per cent of the adults and 93·9 per cent of the nymphs and pupae were killed in 1933, and 91·9 per cent of the adults and 84 per cent of the nymphs and pupae were killed in 1934. With Hardie sprayer, the maximum mortality was 92·8 per cent among adults and 87·4 per cent among nymphs and pupae during 1933, and 81·7 per cent among adults and 75·6 per cent among nymphs during 1934. With Sapom sprayer the mortality was comparatively low (Table II).

Table II

Percentage mortality among adults and nymphs of B. gossypiperda *M. & L., with different insecticides at Khanewal and Okara during 1933 and 1934*

Locality	Insecticides tried	Dates—Fortnight ending	Hardie		Sapom		Orchard Power Sprayer		Unsprayed	Remarks
			Nymphs and pupae	Adults	Nymphs and pupae	Adults	Nymphs and pupae	Adults	Nymphs and pupae	
Khanewal	Rosin compound	15th July	85·9	92·8	67·9	80·7	...	...	3·5	1933
		31st July	87·4	93·7	76·0	80·8	...	...	3·6	
		15th August	83·9	88·7	74·4	74·6	...	...	7·1	
		31st August	80·6	86·3	64·1	63·6	...	...	11·4	
		Average	84·4	90·3	70·6	74·9	...	...	6·4	
Okara	Do.	15th July	...	...	73·4	75·1	78·5	78·6	Ranged between 3·8 to 11·8	
		31st July	...	...	78·4	80·2	84·7	85·7		
		15th August	...	...	84 0	90·8	93·9	95·7		
		31st August	...	...	78·7	83·1	85·9	90·4		
		Average	...	...	78·6	82·3	85·7	87·6	7·2	
Khanewal	Do.	15th July	74·5	81·7	69·8	76·7	...	...	7·2	1934
		31st July	75·6	78·1	69·7	74·1	...	...	7·1	
		15th August	70·9	73·2	59·9	73·6	...	...	3·2	
		31st August	67·6	76·2	52·9	55·3	...	...	7·6	
		Average	72·1	77·3	63·0	69·9	...	...	6·2	
	Fish-oil-soap	15th August	70·6	71·2	51·5	...	...	...	...	
	Tobacco decoction	Do.	59·1	75·2	...	...	...	...	...	
	Kerosene oil emulsion	Do.	64·2	71·0	49·2	63·2	...	...	...	
Okara	Rosin compound	15th July	...	...	71·7	73·8	80·5	85·0	...	
		31st July	...	...	79·8	82·2	84·0	90·6	2·5	
		15th August	...	...	...	...	85·0	88·5	6·1	
		31st August	...	...	...	...	82·6	91·1	7·9	
		Average	...	...	75·7	78·0	83·0	88·8	5·1	
	Rosin soap	15th August	...	...	...	...	83·5	89·8	...	
	Tobacco decoction	Do.	...	...	...	...	71·0	63·8	...	
	Lime-sulphur wash	Do.	...	...	...	...	62·3	45·1	...	

4. Consumption of insecticide.—The consumption of insecticide per acre varied with each machine and, naturally, it also varied with the condition of the crop. During 1933, spraying operations were conducted from 11th July to 31st August, both at Khanewal and at Okara. The Hardie and Sapom sprayers at Khanewal used on an average. 58·2 and 43·3 gallons of insecticide per acre, respectively. The Sapom at Okara consumed 57·1 gallons per acre, while the Orchard Power sprayer consumed 68·4 gallons per acre. The crop at Okara was relatively bushy and more severely infested.

During 1934 the spraying operations were started a little earlier, *i.e.*, on 29th June at Okara and on 3rd July at Khanewal. The crop at the time was very young. The insecticide consumed by Hardie and Sapom sprayers at Khanewal was 51·8 and 43·4 gallons per acre, respectively. At Okara, the Sapom sprayer was used till the 22nd July, after which it was shifted to Sargodha. The insecticide used per acre by this machine during this interval was only 31·5 gallons. This estimate does not represent the average of the season. The Orchard Power sprayer also showed lower consumption, *viz.*, 44·8 gallons per acre, as special care was taken to reduce leakage by using new pipe connections and hoses.

5. Labour charges, fuel and petrol expenses.—During 1933, the cost of manual and bullock labour at Khanewal was calculated at Re. 0-4-0 per acre with Hardie sprayer and Re. 0-6-8 with the Sapom sprayer. At Okara, the cost was Re. 0-7-1 per acre with Sapom and Re. 0-10-8 with the Orchard Power sprayer. These expenses were reduced to Re. 0-3-11, Re. 0-4-8, Re. 0-3-8 and Re. 0-10-3 respectively during 1934 (Table III).

The fuel expenses at Khanewal during 1933 were estimated at Re. 0-1-4 per acre for Hardie and Re. 0-1-2 for Sapom. During 1934, these expenses were reduced by 40·7 per cent and 39·7 per cent, respectively.

The petrol expenses per acre increased from Re. 0-2-0 with Hardie and Re. 0-6-5 with Orchard Power sprayer during 1933 to Re. 0-2-5 and, Re. 0-6-11 respectively, during 1934 (Table III). The increase in petrol consumption was probably due to the machines having seen longer service.

VI. Efficacy of insecticides

The efficacy of an insecticide is judged by the mortality of the pest and its cost. It also depends indirectly on the spraying machine used.

During 1933, almost the entire area was sprayed with rosin compound except an area of 72 acres at Okara, which was sprayed with rosin soap. Both the insecticides were found to be equally effective in killing the pest, but the cost of rosin soap was higher. Dusting with calcium cyanide in the ratio of one part of insecticide to seven parts of road dust and with nicotine sulphate in the ratio of one to three gave an average mortality of 36·2 per cent and 32·7 per cent, respectively, in nymphs and pupae.

During 1934, a number of other insecticides were also tried and their relative cost per acre worked out (Table III). Rosin compound gave maximum mortality with the power sprayers. Rosin soap also gave equally satisfactory results. Fish-oil soap, used at Okara during first fortnight of August, was found to be as effective as rosin compound. Tobacco decoction and kerosene oil emulsion were tried at Okara in the first fortnight of August. The mortality in nymphs and pupae with these was found to be very low. Lime-sulphur was also tried in the second fortnight of August, but did not give satisfactory results.

The cost of insecticide per acre with power sprayers, during 1933, was lowest for rosin compound (Table III). For rosin soap, it was 125 to 154 per cent higher with Hardie and Sapom sprayers, respectively. The cost of Fish-oil soap, Tobacco decoction and Kerosene oil emulsion, when applied with Hardie sprayer in 1934, was found to be 300 per cent, 74 per cent and 71 per cent higher than rosin compound, respectively. Rosin soap, lime-sulphur wash and tobacco decoction, when applied with Orchard Power sprayer, also cost 152 per cent, 66 per cent and 65·5 per cent more than rosin compound applied with the same machine (Table III).

Beside these, a sample of ' Evergreen ' spray received from Kerr & Co., Bombay, was given a trial over 7·5 acres at Khanewal. The insecticide was used in the dilution of 1 : 300 and mortality on an average worked out at 73·0 per cent among nymphs and pupae and 85 per cent among adults. The cost of insecticide was Rs. 3-3-0 per acre.

Rosin compound proved to be the most satisfactory insecticide, both from point of view of insect mortality and cost. Its application against this pest can therefore be recommended with confidence.

VII. Total cost of spraying

In calculating the total cost of spraying per acre, all the items of expenditure, *viz.*, insecticide, labour, petrol, fuel, supervision charges and depreciation, etc., have been taken into consideration (Table III).

During 1933, cost of spraying per acre of cotton crop with rosin compound varied from Re. 1-5-10 with Sapom and Re. 1-9-10 with Hardie sprayer at Khanewal, to Re. 1-11-0 with Sapom and Rs. 3-5-0 with Orchard Power sprayer at Okara. With rosin soap, the cost increased to Rs. 2-5-0 and Rs. 4-5-1 per acre with Sapom and Orchard Power sprayer, respectively. During 1934, the average cost of spraying one acre of cotton crop with rosin compound at Khanewal was Re. 1-2-3 with Sapom and Re. 1-7-9 with Hardie, while at Okara, it was Re. 0-14-3 with Sapom and Rs. 2-9-9 with Orchard Power sprayer. It was thus reduced by 8·1 per cent and 16·4 per cent with Hardie and Sapom, respectively, at Khanewal and by 21·1 per cent with Orchard Power sprayer at Okara. It is possible to reduce the cost still further by paying greater attention to details, such as labour, preparation of insecticide and supervision, etc.

TABLE III

Cost of spraying with different insecticides using different types of machinery during 1933 and 1934.

Locality	Machine used	Insecticide tried	Total area sprayed (acres)	Average daily output of work (acres)	Total solution used per acre (gallons)	Cost of insecticide per acre	Cost of fuel used per acre	Cost of petrol per acre	Pay of mechanic per acre	Labour charges including bullocks per acre	Depreciation charges on machinery, etc., per acre	Miscellaneous charges per acre	Cost of spraying per acre excluding cost of insecticide	Total cost of spraying per acre including all charges
						1933								
						Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.
Khanewal	Hardie	Rosin compound	645	15·0	58·2	0-11-11	0-1-4	0-2-0	0-2-0	0-4-0	0-4-1	0-0-6	0-13-11	1-9-10
	Sapom	Do.	635	14·8	48·3	0-10-0	0-1-2	...	0-0-4	0-6-8	0-3-5	0-0-3	0-11-8	1-5-10
Okara	Do.	Do.	227	9·9	57·4	0-11-8	0-1-1	...	0-0-7	0-7-1	0-6-5	0-0-3	0-15-5	1-11-1
	Do.	Rosin soap	51	9·9	57·4	1-6-0	0-0-5	...	0-0-7	0-7-1	0-6-7	0-0-3	0-14-9	2-5-0
	Orchard Power sprayer	Rosin compound	294	9·5	68·4	0-13-6	0-1-4	0-6-5	0-5-1	0-10-8	0-14-8	0-1-4	2-7-6	3-5-0
		Rosin soap	21	9·5	68·4	1-14-6	0-0-5	0-6-5	0-5-1	0-10-5	0-14-8	0-1-7	2-6-7	4-5-1
						1934								
Khanewal	Hardie	Rosin compound	807	16·1	51·8	0-11-9	0-0-10	0-2-5	0-0-10	0-3-11	0-3-8	0-0-4	0-12-0	1-7-9
		Fish oil soap	40	...	...	2-3-0	0-0-5	0-2-5	0-0-10	0-3-6	0-3-8	0-0-4	0-11-2	2-14-2
		Tobacco decoction	30	...	...	1-4-5	0-1-1	0-2-5	0-0-10	0-4-4	0-3-8	0-0-4	0-12-8	2-1-1
		Kerosene oil emulsion	18	...	...	1-4-1	0-0-6	0-2-5	0-0-10	0-4-0	0-3-8	0-0-4	0-11-10	1-15-10
	Sapom	Rosin compound	779	16·8	43·4	0-9-8	0-0-8	...	0-0-3	0-4-8	0-2-11	0-0-1	0-8-7	1-2-3
		Fish oil soap	70	...	...	1-12-0	0-0-5	...	0-0-4	0-4-11	0-2-11	0-0-1	0-8-8	2-4-8
		Kerosene oil emulsion	12	...	...	1-0-1	0-0-6	...	0-0-3	0-5-4	0-2-11	0-0-1	0-9-1	1-9-2
Okara	Do.	Rosin compound	342	19·0	32·0	0-6-5	0-0-8	...	0-0-3	0-3-8	0-3-2	0-0-1	0-7-10	0-14-3
	Orchard Power sprayer	Rosin compound	313	10·5	44·8	0-9-0	0-0-10	0-6-11	0-3-4	0-10-3	0-10-3	0-1-2	2-0-9	2-9-9
		Rosin soap	102	...	...	1-6-9	0-0-5	0-6-11	0-3-4	0-11-0	0-10-3	0-1-2	2-1-1	3-7-10
		Tobacco decoction	31	...	...	0-14-10	0-1-1	0-6-11	0-3-4	0-9-0	0-10-3	0-1-2	1-15-9	2-14-7
		Lime-sulphur wash	21	...	...	0-15-1	0-0-5	0-6-11	0-3-4	0-8-0	0-10-3	0-1-2	1-14-1	2-13-2

Of the three machines tried during these operations, Hardie Power sprayer was considered to be the most suitable machine for spraying cotton crop. The Sapom was ruled out on account of the low pest mortality obtained, while the Orchard Power sprayer was found to be both expensive as well as cumbersome.

VIII. Yield tests

From a grower's point of view, a control measure is worth adopting only if it brings increased yield sufficient to justify trouble and expenditure on the measure adopted. In order to judge the beneficial affects of these trials, the yield from sprayed and unsprayed fields at all the centres of operation, were collected and statistically compared (Tables IV, V and VI).

During 1933-34, at Khanewal (Table IV) the average increase in yield per acre by spraying American cottons was about one maund. At Okara, where both American and *desi* cottons were sprayed, the average increase in yield per acre in the former type was also one maund. In area under *desi* cotton, sprayed from 11th to 30th July, the maximum increase in yield per acre was 2·22 maunds, but in the area sprayed in the end of August negative results were obtained.

During 1934-35, at Khanewal (Table V) the average increase in yield per acre in American cotton was 1·72 maunds by single spraying and 2·07 maunds by double spraying. For *desi* cotton an average increase of 0·42 maund per acre was obtained. This low increase was probably due to the fact that about 25 per cent of the area was sprayed after 10th of August, an unsuitable time for spraying. The average increase in yield per acre, by spraying *desi* cotton during July was 1·56 maunds. American cotton sprayed in August gave an average increase of 2·03 maunds per acre. This was due to the fact that White-fly attack on these types was very severe in August and spraying was very effective.

At Okara, a nominal increase of 0·34 maund per acre was obtained by spraying American cotton and 2·0 maunds per acre by spraying *desi* cotton (Table VI). The low increase in the former type was on account of the early spraying (July) in Chak No. 4. The crop at this time was very young and the attack of the pest almost nil. Spraying the crop as early as that had no beneficial effect because the plants were subsequently exposed to White-fly attack almost to the same extent as if they had not been sprayed at all. Spraying after 15th July proved better and resulted in an increase of 0·71 maund per acre. There was an increase of 0·73 maund per acre in crop sprayed during August.

TABLE IV

Comparative yields of cotton from sprayed and unsprayed areas during 1933-34

Locality	Type of cotton	Chak No.	Sprayed		Unsprayed		Average increase in yield per acre in maunds	Statistical analysis			Statistical remark	Net return to the cultivator in Rs. due to increase in yield per acre	Remarks.
			Total area in acres	Average yield per acre in maunds	Total area in acres	Average yield per acre in maunds		No. of degrees of freedom 'n'	Fisher's 't'	Probability 'P'			
												Rs. a. p.	
Khanewal	American	75	274·3	13·20	...	...	...						
		81	148·0	11·85	...	...	...						
		82	292·9	12·10	102·7	11·82	+0·28						
		83	163·1	13·40	25·90	11·40	+2·00						
		85	120·7	11·73	38·0	11·05	+0·68						
		86	139·3	13·95	...	...	...						
		87	136·7	12·88	...	...	...						
		Average		12·73	...	11·42	+1·31	6	2·471	$0·05 > P > 0·02$	Significant	7-0-8	Calculated @ Rs. 5-6-0 per maund

Okara	American	3	156·0	8·93	16·1	7·66	+1·27						
		4	146·4	9·33	80·6	8·34	+0·99						
		12	50·8	12·25	36·2	11·50	+0·75						
		Average			10·17	...	9·17	+1·00	2	6·687	0·05>P>0·02	Do.	5-6-0	Ditto.
	Desi	2	109·9	10·06	10·6	9·76	+0·30						
		4	80·1	11·46	110·8	9·24	+2·22	...	...	...	...	...	Sprayed from 11th to 30th July
		12	56·1	9·90	57·2	10·05	—0·15	...	...	...	...	...	Sprayed after 3rd week of August
		Average			10·47	...	9·68	+0·79	2	1·087	0·4>P>0·3	Not significant	3-5-9	Calculated @ Rs. 4-4-0 per maund

TABLE V

Comparative yields of cotton from sprayed and unsprayed areas at Khanewal during 1934-35

Type of cotton	Chak No.	Month and type of spraying	Period of spraying	Sprayed		Unsprayed		Average increase in yield per acre in maunds	Statistical analysis			Statistical remark	Net return to the cultivator in Rs. due to increase in yield per acre	Remarks
				Total area in acres	Average yield per acre in maunds	Total area in acres	Average yield per acre in maunds		No. of degrees of freedom 'n'	Fisher's 't'	Probability 'P'			
													Rs. a. p.	
American .	81	July (Single sprayed)	13th to 18th July	110·4	15·67	39·9	13·72	+1·95						
	82		19th July to 1st August.	161·2	12·75	63·5	11·42	+1·33						
	83		3rd to 10th July .	34·3	8·0	37·8	7·37	+0·63						
	85		11th to 12th July	23·1	7·95	42·2	6·27	+0·68						
			Average . .	...	11·10	...	9·70	+1·40	3	2·825	$0·1>P>0·05$	Not significant	9-8-7	Calculated @ Rs. 6-13 per maund
	75	August (Single sprayed)	11th to 19th Aug.	201·8	11·47	89·5	10·72	+0·75						Average increase for American cotton by single spraying was 1·72 mds. per acre
	85		3rd to 5th Aug. .	40·6	9·22	42·7	6·27	+2·95						
	86		20th to 27th Aug.	146·1	10·55	13·6	8·42	+2·13						
	87		25th to 26th Aug.	40·0	9·10	81·6	6·80	+2·30						
			Average . .	...	10·08	...	8·05	+2·03	3	3·727	$0·05>P>0·02$	Significant.	15-10-8	Calculated @ Rs. 6-13 per maund

	82	Double sprayed	19th July to 1st Aug. and 28th to 31st Aug.	99·7	12·55	63·5	11·42	+1·13					
	83		3rd to 10th July and 6th to 10th Aug.	114·8	8·53	37·8	7·37	+1·16					
	85		11th to 12th July and on 2nd Aug.	26·3	10·18	42·7	6·27	+3·91					
			Average . .	...	10·42	...	8·35	+2·07	2	1·308	0·4>P>0·3	Not significant	15-11-0	Ditto.
Desi .	81	July (Single sprayed)	13th to 18th July	51·7	16·87	14·8	14·32	+2·55					
	82		19th July to 1st Aug.	124·8	14·22	30·3	13·27	+0·95					
	83		3rd to 10th July .	64·3	7·45	21·3	6·40	+1·05					
			11th to 12th July	6·9	10·17	34·9	8·52	+1·65					
			Average . .	...	12·18	...	10·62	+1·56	3	4·272	0·05>P>0·02	Significant	8-6-10	Calculated @ Rs. 5-7 per maund
	75	August (Single sprayed)	11th to 19th Aug.	61·5	13·22	7·0	14·37	+1·05					
	85		3rd to 5th Aug. .	27·2	8·75	34·9	8·52	+0·23					
	86		20th to 27th Aug.	31·8	10·82	45·7	13·12	—2·30					
			Average . .	...	10·96	...	12·00	—1·04	2	1·425	0·3>P>0·2	Not significant	...	Average increase for *desi* per acre was 0·42 maund

TABLE VI

Comparative yields of cotton from sprayed and unsprayed areas at Okara and Sargodha during 1934-35

Locality and type of cotton	Chak No.	Month and type of spraying	Period of spraying	Sprayed		Unsprayed		Average increase in yield per acre in maunds	Statistical analysis			Statistical remarks	Net return to the cultivator in Rs. due to average increase per acre	Remarks
				Total area in acres	Average yield per acre in maunds	Average area in acres	Average yield per acre in maunds		Degrees of freedom 'n'	Fisher's 't'	Probability 'P'			
													Rs. a. p.	
Okara—	4	July (Single sprayed)	28th June to 15th July.	175·8	8·00	16·0	8·44	+0·44						
American .	12		16th to 31st July	101·5	8·12	17·0	7·41	+0·71						
			...	21·8	6·72	10·3	6·75	—0·03						
			Average . .	...	7·61	...	7·54	+0·07	2	0·226	0·9>P>0·8	Not significant	4-14-0	Calculated @ Rs. 6-13 per maund
	3	August	1st to 24th Aug. .	114·5	7·48	10·3	6·75	+0·73						
	3	(Double sprayed)	28th July to 23rd Aug. and 15th to 22nd Aug.	15·8	7·55	10·3	6·75	+0·85						
	4		28th June to 24th July and 25th to 28th Aug.	19·2	8·35	16·0	8·45	+0·10						
			Average . .	...	7·94	...	7·60	+0·34					4-5-1	Ditto. Replications too few

Desi .	4	July .	28th June to 15th July.	173·4	9·17	35·2	7·27	+1·90				
	12		16th to 31st July.	87·2	11·88	36·6	9·01	+2·87				
	3		...	12·2	10·35	86·4	8·84	+1·51				
			Average . .	...	10·47	...	8·37	+2·10	2	5·177	$0·05>P>0·02$ Significant	11-6-8 Calculated @ Rs. 5-7 per maund
Sargodha—American	...		28th July to 7th Aug.	27·3	11·05	10·0	9·18	+1·87				
Desi .			28th July to 7th Aug.	13·0	6·93	24·7	6·45	+0·48				
	Square No.											
American	34/1/½	...	...	0·431	13·27	0·431	12·87	+0·40				
	34/2/½	...	...	0·431	12·57	0·431	10·01	+2·56				
	A.B.8/2	...	...	1·250	11·01	1·250	8·42	+2·59				
	11E. ½	...	...	1·250	13·47	1·250	11·02	+2·45				
	34/8	...	...	0·550	19·40	0·500	15·60	+3·80				
			Average . .	...	13·94	...	11·58	+2·36	4	4·303	$0·02>P>0·01$ Significant	16-1-3 Calculated @ Rs. 6-13 per maund
Desi .	34/3/½	...	...	0·606	11·07	0·606	9·27	+1·80				
	A/3	...	...	1·231	12·85	1·231	9·45	+3·40				
			Average	...	11·96	...	9·36	+2·60		Replications too few		15-2-2 Calculated @ Rs. 5-7 per maund

Spraying the *desi* cotton during July proved quite effective, yielding an average increase of 2·10 maunds per acre.

At Sargodha, single spraying of American cotton gave an average increase of 2 maunds per acre, while for *desi* cotton, there was an increase of 0·48 maund only per acre. This was on account of the late spraying of this type (Table VI).

Further experiments were conducted at Sargodha, to test the efficacy of spraying in the following manner. In four squares each line under American cotton was divided lengthwise in two equal halves and in the fifth square it was divided across with equal number of cotton rows. Half of each line was sprayed and the corresponding half was left as control. Thus an area of 4·26 acres was sprayed in five different squares. In this way, most of the fluctuating factors, *viz.*, rotations, soil variations, irrigation and date of sowing, etc., were to a great extent eliminated. There was an average increase of 2·36 maunds per acre for American cotton and 2·60 maunds per acre for *desi* cotton.

It is clear from the above data that spraying the cotton crop with Rosin compound is beneficial against White-fly of cotton and results in increased yield. But the time of spraying is an important factor. The best time for spraying *desi* cotton is July, while spraying in August is definitely harmful. For American cotton, single spraying in August, before the crop has grown too bushy, is good, but double spraying, once in July and again in August, is better.

The net gain to the cultivator from the increase in yield per acre, calculated on the basis of prices prevailing in 1933 and 1934 for American and *desi* cottons, is given in the tables for yield data.

IX. Summary

Field-scale spraying trials were conducted against *B. gossypiperda* M. & L., a serious pest of cotton in the Punjab. A number of insecticides were tried.

Spraying the infested crop with rosin compound gave very satisfactory results. The cost of spraying with different types of machinery and insecticides has been worked out.

In all 1,873 acres of cotton crop were sprayed during 1933 and 2,460 acres during 1934. Machines of the type of cart sprayers proved better. Hardie Power sprayer with a 2 H. P. pump was found to be the most satisfactory.

Mortality of the pest was, on the whole, greatest with Orchard Power sprayer. The Hardie sprayer came next.

The cost of spraying with rosin compound varied from Re. 1-2-4 per acre with Sapom to Re. 1-7-8 with Hardie and Rs. 2-9-9 with the Orchard Power sprayer. It is possible to reduce the cost still further by paying more attention to details.

Spraying *desi* cotton in July and American cotton in August proved effective in increasing the yield. The net gain per acre to the cultivator justified expenditure on spraying.

NOTES ON THE LIFE-HISTORY AND HABITS OF *DACUS BREVISTYLUS* BEZZI (FAMILY TRYPETIDAE), A PEST OF *COCCINIA INDICA* FRUITS

BY

M. C. CHERIAN, B.A., B.Sc., D.I.C.

AND

C. V. SUNDARAM

Agricultural Research Institute, Coimbatore

(Received for publication on 31st December 1937)

(With Plate VI)

Introduction

Coccinia (*Cephalandra*) *indica* known in Telugu as *dondakaya* and in Tamil as *kovaikkai* is one of the vegetable crops in the Northern Circars and was introduced into Coimbatore not long ago. This cucurbit creeper grows well in loamy red soils under irrigated conditions. The plant is generally raised as an annual but it can also be kept as a perennial crop for over three or four years. The first harvest comes in April. On an average there will be about fifteen pickings in a season, the maximum yield being obtained in April and May. The pickings are continued till September. In Coimbatore this fruit is subject to the attack of a Trypetid—*Dacus brevistylus*—and the present paper gives information on the life-history and habits of this pest under South Indian conditions.

History of the pest

Dacus brevistylus belonging to sub-family Dacinae was originally described by Bezzi [1908]. This species is widely distributed in Africa and Europe. Bezzi [1914] for the first time recorded this species from India on melon from Sidhout (Cuddapah District). Silvestri [1914] gave a brief description of the adult flies. Senior White [1924] recorded a few more localities in India where the fly had been observed. The first record of the pest on *Coccinia* fruit is by Ramakrishna Ayyar [1935].

Description of the pest

The description of the fly by Silvestri [1914] is given below :—

Female (Fig. 9).—" Body more or less dark fulvous in colour ; face with two large black spots, and one brown spot on the peristome near the lower part of the eyes ; thorax with the scutum a little darker than the rest of the body, with a median presutural line and two sub-median post-sutural black spots, which may be more or less evident (very evident in the alcoholic specimens, almost invisible in those preserved dry) ; humeral calli, suture, pleurae opposite the suture, hypopleural spot and the scutellum yellowish white or ochraceous. Wings similar to those of the preceding species—*Dacus vertebratus* Bezzi. Scapulars in two pairs. Seventh segment 1·5 mm. ; ovipositor 1·56 mm. in length. Length of body 6-7 mm. "

Male (Fig. 8).—" Sides of the third abdominal segment provided with a posterior row of setae. Forceps of the copulatory organ with the outer side of the lower lamina longer than the inner, attenuated and arcuate. "

Habits of the pest

The time of the emergence of the adults both in the field and in the laboratory was noted to be from 8 to 10 A.M. From the observations made so far the pre-oviposition period seems to be at least four days.

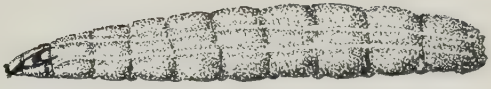
The female is very active just prior to laying eggs. It goes about over the fruits a number of times and selects a convenient spot for egg laying which is very often near the stalk. This habit probably facilitates the dropping of the fruits at the time the maggots are full grown and ready for pupation which, under normal conditions, takes place in the soil. The female, after selecting the spot for oviposition, stretches out its ovipositor, with which it pricks the fruit and a liquid of dry white colour oozes out of the puncture. The female flies off for a while, comes back and licks up the fluid collected in the form of a globule. Again she thrusts her ovipositor in the same place and moves it up and down a number of times. In one puncture as many as eight eggs are laid. Three such punctures have been noticed in a single fruit containing a maximum of twenty-two eggs. When the maximum number of eggs exceeds ten or twelve, the maggots which hatch out and feed inside the fruit do not get enough food, with the result that the pupæ and adults resulting from these are under-sized.

The liquid oozing out through the puncture made on the fruit for oviposition dries up in the form of a crest, dark brown in colour. Two days after egg laying a small hollow is seen on the fruit at the place of oviposition, and the adjoining area begins to turn soft and brown. In about four or five days the whole fruit turns brown by which time the maggots have completely devoured its contents, leaving only the shrivelled-up skin and seeds. If the maggots are only a few in number a portion of the fruit still remains fresh but the fruit in either case drops to the ground. Within a day the maggots come out of the fruit and enter the soil for pupation.

1

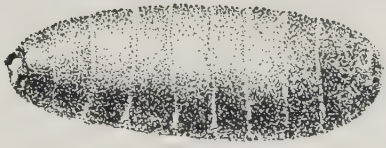
3

4



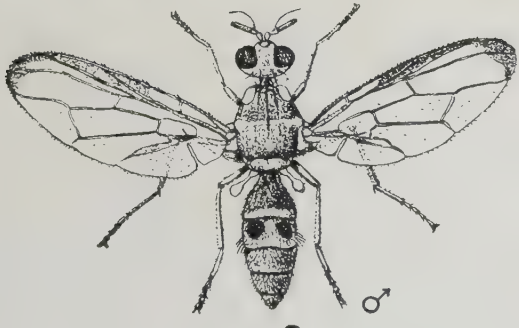
5

2

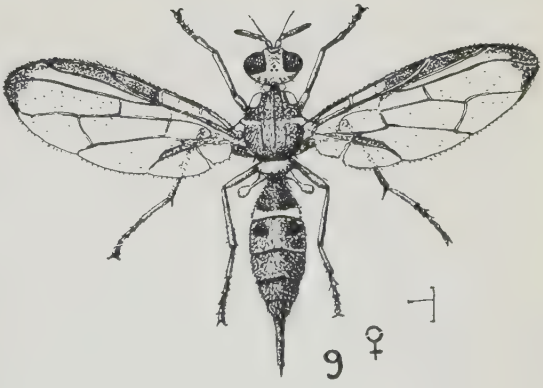


7

6



8 ♂



9 ♀

1. *Coccinia* fruit; 2. Transverse section of fruit showing eggs; 3. The egg (×7); 4. Just hatched maggot (×7); 5. Full grown maggot (×4); 6. Longitudinal section of fruit showing maggots; 7. Puparium (×6); 8. Adult male (×3½); 9. Adult female (×3½)

Life-history

Egg (Plate VI, figs. 2 & 3).—Generally three to four eggs are laid in each puncture, the eggs being found adhering to the seed. The egg is about 2·5 mm. in length, shiny white, slightly curved, cylindrical in shape and narrow at one end. The incubation period varied in the laboratory from a little less than two days to four days between 27th September and 17th October 1935 (eleven observations).

Maggot.—The freshly hatched maggot (Plate VI, fig. 4) has a tapering head and black hook-like mouth-parts and is about the same size as the egg. When full grown (Plate VI, fig. 5) it is 8 mm. long and 1·4 mm. broad. According to Silvestri [1914] the mandibular hooks of the mouth-parts are provided each with a pre-apical tooth and the oral lobes, which are well developed, have each fifteen laminate ridges. There are several dorsal spines on the first three post-cephalic segments and a few on the fourth and the fifth. Each anterior spiracle is provided with fourteen to sixteen lobes. The maggots when full grown drop either with the fruit or by themselves and pupate in the soil. In the field, though the maggots drop in one place from a fruit, they disperse slightly before they enter the soil for pupation. The depth of the soil at which they pupate varies from half to two inches depending on the hardness or looseness of the soil. The larval period in the laboratory was four to six days in October 1935 (eight observations).

Puparium.—The puparium (Plate VI, fig. 7) is elliptical and brownish in colour and about $4\frac{1}{2}$ to $5\frac{1}{2}$ mm. long and 2 to $2\frac{1}{2}$ mm. broad. The pupal period was eight to ten days (nine observations).

Longevity of flies.—Longevity records of female and male flies kept in cages and fed with honey solution show that during October, November and December, the maximum longevity of a male was sixty days and that of a female forty-two days, the average for thirty flies of both sexes being twenty-eight days. The adult flies lived without food for three or four days only.

Total life-cycle.—The life-history data have been summarised in Table I. It will be seen that the total life-cycle of the fly ranges from fifteen to seventeen days. The temperature and humidity at which the life-history of the fly was studied are given in Table II. Under Coimbatore conditions there are about six broods in the year.

TABLE I

Life-history records of **Dacus brevistylus**

Egg laid on	Hatched on	Egg period (days)	Pupated on	Larval period in days	Adult emerged on	Pupal period (days)	Total life-cycle in days
9th Oct. 1935 .	11th Oct. 1935 .	2	15th Oct. 1935 .	4	24th Oct. 1935 .	9	15
10th Oct. 1935 .	12th Oct. 1935 .	2	15th Oct. 1935 .	4	24th Oct. 1935 .	9	15
11th Oct. 1935 .	13th Oct. 1935 .	2	17th Oct. 1935 .	5	27th Oct. 1935 .	10	17
12th Oct. 1935 .	14th Oct. 1935 .	2	18th Oct. 1935 .	5	28th Oct. 1935 .	10	17
14th Oct. 1935 .	16th Oct. 1935 .	2	21st Oct. 1935 .	6	29th Oct. 1935 .	8	16
17th Oct. 1935 2-20 P.M. .	19th Oct. 1935 10-15 A.M. .	One day and 2 hrs.	23rd Oct. 1935 .	5	1st Nov. 1935 .	9	16
18th Oct. 1935 .	20th Oct. 1935 .	2	24th Oct. 1935 .	5	2nd Nov. 1935 .	9	16

TABLE II

Temperature and humidity at which the life-history of Dacus brevistylus *was studied*

	September 1935	October 1935	November 1935	March 1936
Mean minimum temperature in shade (°F.) . . .	62·2	70·9	68·1	70·5
Mean maximum temperature in shade (°F.) . . .	89·3	87·8	86·1	94·1
Mean humidity at 8 hours (per cent)	69·1	78·9	74·2	73·4

OTHER FOOD PLANTS OF THE PEST

The fly has been noted to breed in captivity on snake-gourd, bitter-gourd, cucumber and melons. From field collections of these fruits also adults have been reared out.

OTHER FLIES REARED FROM *COCCINIA* FRUITS

In addition to *Dacus brevistylus* found in large numbers on this fruit, the cucurbit fly, *Dacus cucurbitae* Coq., has also been reared occasionally.

PARASITES

From fruits collected from the field for over a period of eight months, only half a dozen hymenopterous parasites of the species *Opius incisi* were collected. But it is not possible to say definitely that these are parasites of *Dacus brevistylus*, as from the infested fruit from which parasites were bred two specimens of *Dacus cucurbitae* also emerged.

LOCALITIES IN WHICH THE PEST HAS BEEN NOTED

The fly has been noted in the following places in the Madras Presidency :— Coimbatore, Kollegal, Mettuppalayam and Vellaikkinar in Coimbatore District ; Adoni and Hagari in Bellary District ; Taliparamba in Malabar ; Tripli-cane (Madras) ; and Sidhout (Cuddapah District).

REMEDIAL MEASURES

Trials of essential oils such as citronella to attract adult flies were not successful. In the field, it is easy to distinguish the attacked fruits from the unattacked ones by the characteristic straw-colored, dried-up liquid on the former. Such attacked fruits can be hand-picked and destroyed to reduce further infestation.

REFERENCES

Bezzi, M. (1908). *Boll. Lab. Zool. Portici* **3**, 91
————(1914). *Bull. Ent. Res.* **5**, 154
Ramakrishna Ayyar, T. V. (1935). *Madras Agric. J.* **23**, 127
Senior White (1924). *Cat. Ind. Insects* **4**, 1
Silvestri, F. (1914). *Board of Agric. & Forestry, Hawaii, Division of Entomology, Bull.* **3**

A REVIEW OF THE LITERATURE ON THE NUTRITIVE VALUE OF PULSES

BY

R. K. PAL

Liaison Officer between Human Nutrition and Agricultural Research

(Received for publication on 13th May 1938)

The pulses form a very important constituent of the dietary all over India. For various reasons, the people as a rule, are not in the habit of taking much proteins of animal origin and as such depend on vegetable proteins, the bulk of which comes from pulses. Until recently there has not been done much work on the investigation of the nutritive value of the different varieties of pulses that are grown in India. The *Health Bulletin* No. 23 [1937] embodies the composition of different pulses and shows their nutritive value on the basis of total protein, mineral and vitamin contents. " Shanghai Foods ", special report series No. 8 [1937] of the Chinese Medical Association also mentions the composition of some of them, as worked out by the Chinese workers. But it is erroneous to assess the nutritive value of pulses as a source of body-building material and also for making up the wear and tear of tissue in the process of living, on the basis of total protein in them. It is equally important to know the biological value, digestibility and the percentage of the essential amino-acid components of the beans. These problems have been studied by very few workers like, Niyogi *et al.* [1931, 1,2 ; 1932], Basu and his associates [1936 ; 1937] and Swaminathan [1937, 1,2] in India ; Adolph and Kiang [1920], Tso [1927], Kim [1928], Lo [1934], Chen [1930] and Adolph and Chiang [1935] in China ; Osborne and Mendel [1907, 1908], Sherman [1929] and Heller [1927] in America ; and Chick and Delf [1919], and Miller and Robins [1934] in England.

The quantitative analytical results of workers of different countries differ a good deal and even amongst Indian workers (Niyogi *et al.* at Bombay, Basu and co-workers at Dacca in Bengal and Swaminathan at Coonoor in South India), there is no uniformity of quantitative estimations. However, it is interesting to compare the results obtained in India by these workers. Table I shows a comparative study of the digestibility coefficient, biological value, and net protein value (side by side with the total protein content), at 10 per cent level of intake of eleven different pulses commonly used in India.

The most important protein fraction of the pulses is a globulin moity. Niyogi and co-workers [1931, 1, 2 and 1932] have found out the percentage composition of the different amino-acids of the globulin of the pulses expressed as per cent of protein. Table II shows the amino-acid constitution of common Indian pulses on a comparative basis, as analysed by Niyogi *et al.* Basu *et al.* [1937] found out the amino-acid constitution of the glutelin factor of two of the pulses, green gram (*Phaseolus radiatus*) and lentils (*Lens esculenta*) and that of the proteins of khesari (*Lathyrus sativa*) precipitated at different saturations of ammonium sulphate. These figures have been incorporated in Tables III and IV respectively.

If we consider the merit of different pulses as based on the results enumerated in the above tables, from different points of view, such as total protein content, biological value, digestibility, net protein value and percentage of the four important essential amino-acids (cystine, tyrosine, tryptophane and histidine), the different members of the group will range themselves in the order shown in Table V.

From the tabulated list (Table V) of different pulses it is rather difficult to say which is the best pulse as a source of protein available for tissue building. If, however, we allot two marks each for biological value and digestibility and one mark for each of the total protein content, net protein value, and percentages of cystine, tyrosine, tryptophane and histidine it is possible to obtain a rough indication as to which are the best types. Table VI shows the respective merits of different pulses as a result of allotment of marks on lines indicated above.

Bengal gram (*Cicer arietinum*) and black gram (*Phaseolus mungo*), both stand first in order of merit and green gram (*Phaseolus radiatus*), lentil (*lens esculenta*), cow pea (*Vigna catjang*) and soya bean (*Glycine hispida*) stand second in the list. This finding is quite in accordance with what Niyogi, Narayana and Desai [1931] observed regarding *Cicer arietinum* " that it is not only more digestible but its proteins are better assimilated than those of other pulses..... *Cicer arietinum* appears to be the best protein food because of its high net protein value." Heller [1927] also found the *mung* bean protein superior to that of many members of the bean family though it was deficient in cystine. Tso [1927] also studied the *mung* bean (*Phaseolus*

mungo L. ?) and while he found the proteins biologically complete, he stated that it was deficient in lime and sodium chloride although it was rich in vitamin B and had a moderate amount of vitamin A. So also Kim [1928] has shown that by germination the sprouted *mung* bean develops a high content of vitamin B and C. The finding of Heller [1927] that *mung* bean is deficient in calcium does not find confirmation in the hands of workers at Coonoor [*Health Bulletin*, No. 23] according to whom the mineral contents of the Bengal gram and green gram are almost the same, with this difference only that the carotene (vitamin A) content of the first is much higher than that of the second, whereas, vitamin B content of the latter is much higher than that of the former.

According to Basu *et al.* [1936] green gram (*Phaseolus mungo* ?) is superior to the lentil as a source of protein. These workers mention the botanical name *Phaseolus mungo* for green gram which is a misnomer. The botanical name for green gram is *Phaseolus radiatus*. However considering various factors as shown above it appears that green gram (*Phaseolus radiatus*) and lentils (*Lens esculenta*) appear to be equally good. Niyogi *et al.* [1932] observe that proteins of *Lens esculenta* are highly digestible, while those of *Vigna catjang* have a high biological value. Adolph and Chiang [1935] isolated five proteins of which glutelin has a high content of cystine and the albumin and two globulins are high in lysine.

Swaminathan's [1937, 2] interesting work consisted of comparing the biological values of proteins of pulses combined with rice and also with rice and skimmed milk powder, for maintenance measured by balance sheet method, with that of the biological value for growth and maintenance assessed by growth method. These are shown in Table VII.

According to him, of all the pulses given with raw milled rice, green gram is the best ; next comes red gram and then Bengal gram, soya bean and black gram follow in order of merit. Similarly green gram stands first in its value for maintenance and growth when given in combination with raw milled rice and skimmed milk powder, then Bengal gram, black gram, red gram, and soya bean, in spite of the latter's very high protein content. It is almost useless as a source of protein for growth and maintenance to the rice-eating people.

Regarding the mineral content, green gram (*Phaseolus radiatus*) and lentil are almost identical so far as calcium and phosphorus are concerned, but the iron content of the former is four times higher than that of the latter. The cow gram (*Vigna catjang*) is very deficient in calcium, and all the more richer in phosphorus with a mean iron value between the first and the second. As to the vitamin contents, lentil is very rich, green gram moderately so and cow gram rather poor in vitamin A (carotene), lentil has got less amount of vitamin B_2 than the other two, while lentil and green gram are the same regarding vitamin B_1 content. Taking all these facts into consideration green gram appears to be slightly better than the other two, because of its very high iron content. Lentil is comparatively better than the cow gram, in view of its higher vitamin A as well as B contents.

So far as protein value of soya bean (*Glycine hispida*) is concerned, it appears to be not better than the pulses like *Phaseolus radiatus*, *Lens esculenta* and *Vigna catjang*, on the other hand it is definitely inferior to *Cicer arietinum* and *Phascolus mungo*. This is quite contrary to the findings of Osborne and Mendel [1917] who in their original studies concluded that the soya bean protein reacted like animal protein. But considering the high fat (19·5 per cent), as well as phosphorus (0·689 per cent) and iron (11·50 mgs. per cent) contents, its total food value is definitely much higher than that of any other pulse. This food value has been further enhanced by the presence of vitamin B_1 which is almost three times as much as vitamin B_2 as dried milk powder and also vitamin B_2 two-thirds as much [Wan, 1932]. According to Miller [1936] " compared with most green vegetables it is unusually rich in good protein, fat, calcium, iron and phosphorus and it is a very good source of vitamins A, B and G." Not much work has been done in India on this pulse which is not very commonly grown in Indian soil. The question is whether, in view of the above findings, extensive cultivation of this pulse should be advocated or not, to improve the nutrition of the people in general. Some of the advantages have just been mentioned but there are some disadvantages too, which may be mentioned below :—

(1) People are not accustomed to take soya bean,

(2) It does not possess a very agreeable taste and is therefore not commonly used as *dhal*,

(3) The soya bean preparations require some skill and are only learnt with some difficulty,

(4) Its value as a source of available protein was over-estimated. This has been proved so by analytical results.

These disadvantages considerably outweigh the advantages of its value as a food in this country. On the other hand it appears that either Bengal gram or pulses of the *Phaseolus* group which are better as a source of protein and are rich in mineral and vitamin contents may prove better than soya bean, if taken with some type of vegetable fat. It will therefore do well

to popularise the indigenous pulses like Bengal gram, black gram, green gram and lentils, than to introduce a new bean the merits of which are not well established.

Conclusions

(1) So far as the nutritive value of the pulses alone is concerned, Bengal gram (*Cicer arietinum*) and black gram (*Phaseolus mungo*) stand first in the list and are alike in mineral and vitamin contents.

(2) Greem gram (*Phaseolus radiatus*) and lentil (*Lens esculenta*) come next in the order of merit. Cow gram (*Vigna catjang*), although it appears to be equally good, does not come to the same level as the other two crops, in respect of the mineral and vitamin contents.

(3) Soya bean as a member of the second group has got a high food value, not as a source of available protein but because of its high fat, mineral and vitamin contents. So there is no special advantage in advocating its cultivation in preference to other indigenous pulses like Bengal gram, black gram, green gram and lentils.

(4) When pulses are eaten with rice, green gram (*Phaseolus radiatus*) and red gram (*Cajanus indicus*) appear to act better than Bengal gram or any other variety and when they are eaten with rice and milk or milk products, green gram (*Phaseolus radiatus*) is the best, the next best being Bengal gram (*Cicer arietinum*).

Summary

Bengal gram has proved to be the best of all the pulses. Green gram is also very good especially when combined with rice or rice and milk products. Black gram has high nutritive value as a protein. Other pulses such as lentil or red gram may be taken only occasionally. Introduction of soya bean is not necessary in this country.

REFERENCES

Adolph, W. H. and Chiang, H. C. (1935). *Chin. J. Phys.* **9,** 347

Adolph, W. H. and Kiang, P. C. (1920,1). *Chin. J. Phys.* **34,** 268

——————————————— (1920, 2). *Nat. Med. J. China* **6,** 40

Basu, K. P.; Nath, M. C.; Ghani, M. O. (1936). *Ind. Med. Res.* **23,** 789, 811

Basu, K. P.; Nath, M. C.; Ghani, M. O.; Mukherjee (1937). *Ind. Med. Res.* **24,** 1027

Chen, T. T. (1930). *Chin. J. Phys.* **4,** 73

Chick, H. and Delf, E. M. (1919). *Biochem. J.* **13,** 149

Health Bulletin No. **23** (1937). (I. R. F. A.), pp. 22, 47

Heller, V. G. (1927). *J. Biol. Chem.* **75,** 435

Kim, C. S. (1928). *China Med. J.* **42,** 337

Lo, T. Y. (1934). *Nat. Univ. Peiping Nutr. Bull.* B **1,** 13, 27

Miller, C. D. and Robins, R. C. (1934). *J. Agric. Res.* **49,** 161

Miller, H. W. (1936). *Chin. Med. J.* **50,** 450, 459

Osborne, T. B. and Mendel, L. B. (1907). *J. Biol. Chem.* **3,** 213

——————————————— (1908). *J. Biol. Chem.* **5,** 187, 197

Niyogi, S. P.; Narayana, N. and Desai, B. C. (1931, 1). *Ind. J. Med. Res.* **18,** 1217

——————————————— (1931, 2). *Ind. J. Med. Res.* **19,** 475

——————————————— (1932). *Ind. J. Med. Res.* **19,** 859, 1041

'Shanghai Foods' (1937). (Chinese Medical Association), pp. 12-15, 38, 40

Sherman, H. C. (1929). *Philip J. Sci.* **38,** 47

Swaminathan, M. (1937, 1). *Ind. J. Med. Res.* **24,** 767

——————————————— (1937, 2). *Ind. J. Med. Res.* **25,** 57, 381, 399

Tso, E. (1929). *Chin. J. Phys.* **3,** 353

Wan, S. (1932). *Chin. J. Phys.* **5,** 353 ; **6,** 35

TABLE I

Digestibility coefficient, biological value and net protein value, at 10 per cent level of intake of different pulses

No.	Pulses	Botanical names	Digestibility per cent			Biological value per cent			Net protein value			Total protein value		
			Niyogi and co-workers	Basu and co-workers	Swaminathan	Niyogi *et al.*	Basu *et al.*	Swaminathan	Niyogi *et al.*	Basu *et al.*	Swaminathan	Niyogi *et al.*	Basu *et al.*	Swaminathan
1	Bengal gram	*Cicer arietinum*	76	...	86	78	...	62	16·68	...	11·78	28·14	...	21·68
2	Green gram	*Phaseolus radiatus*	83	90	86	60	52	51	13·92	10·4	10·44	25·25	23·26	24·77
3	Red gram	*Cajanus indicus*	71	...	75	74	...	85, 72	13·47	...	12·23	25·63	...	23·57
4	Field pea	*Pisum sativum*	70	70	...	62	48	...	11·10	11·7	7·67	25·57	27·1	24·63
5	Lentil	*Lens esculenta*	78	90	88	58	32	41	12·86	6·5	9·27	28·74	22·6	24·11
6	Khesari	*Lathyrus sativa*	...	...	...	...	41	...	...	...	...	...	32·2	...
7	Black gram	*Phaseolus mungo*	82	...	78	64	...	62	13·81	...	11·36	25·00	...	23·50
8	Cow gram	*Vigna catjang*	58	...	78	72	...	45	10·86	...	8·47	26·52	...	24·12
9	Field bean	*Dolichos lablab*	65	...	76	57	...	41	10·65	...	7·67	28·74	...	24·63
10	Soya bean	*Glycine hispida*	...	90	76	...	58	54	...	20·2	16·42	...	41·2	42·41
11	Horse gram	*Dolichos biflorus*	59	...	73	67	...	66	10·43	...	10·65	28·4	...	22·12

TABLE II

Amino-acids of the globulin of pulses expressed as per cent of protein ash and moisture free

(*Niyogi and co-workers*)

	Bengal gram	Green gram	Red gram	Field pea	Lentil	Black gram	Cow gram	Field bean	Horse gram
Lysine	7.42	7.7	7.03	8.19	6.70	6.16	5.96	7.27	8.15
Histidine	1.42	1.46	2.56	1.90	2.77	3.46	2.21	1.38	2.38
Arginine	10.29	7.90	5.84	9.50	10.35	6.37	7.45	8.09	6.00
Arginine	11.85	8.80	6.91	10.64	11.53	7.17	7.91	8.72	7.07
Cystine	2.02	1.59	1.58	1.12	1.62	3.51	1.89	1.54	1.24
Tyrosine	2.95	3.53	3.12	1.98	3.56	3.63	3.74	4.34	4.01
Tyrosine	4.90	3.92	3.35	2.32	3.92	3.87	3.88	5.11	5.74
Tryptophane . . .	0.46	0.59	0.46	0.51	0.71	0.80	0.80	0.44	0.76
Tryptophane . . .	0.46	0.74	..	..	0.62	0.84	0.59	0.42	1.02

TABLE III

Amino-acids of the glutelin of pulses expressed as per cent of total nitrogen
(Basu and associates, 1937)

	Green gram (*Phaseolus mungo*)	Lentils (*Lens esculenta*)
Arginine	4.88	9.33
Histidine	5.81	0.96
Cystine	1.30	0.84
Lysine	4.99	10.44
Tyrosine	3.30	3.97
Tryptophane	0.52	0.59

TABLE IV

Amino-acids of the proteins of khesari (Lathyrus sativa) *precipitated at different saturations, expressed as the percentage of total nitrogen*
(Basu and co-workers, 1937)

	Precipitated by 3/10 ammonium sulphate	Precipitated by 1/2 ammonium sulphate	Precipitated by ammonium sulphate
Arginine	5.74	3.93	10.45
Histidine	2.83	1.45	8.24
Cystine	0.71	0.53	0.25
Lysine	7.35	12.83	10.75
Tyrosine	3.67	2.91	3.38
Tryptophane	0.65	Trace	0.74

TABLE V

Position in order of merit from various stand-points

Basis of consideration	1	2	3	4	5
Total protein content	Soya bean	Field bean	Lentil	Bengal gram	Cow gram
Biological value	Red gram	Bengal gram	Horse gram	Black gram	Cow gram
Digestibility	Lentil	Green gram	Soya bean	Bengal gram	Black gram
Net protein value	Soya bean	Bengal gram	Red gram	Black gram	Green gram
Essential amino-acids—					
Cystine	Black gram	Bengal gram	Cow gram	Lentil	Green gram
Tyrosine	Soya bean	Field bean	Bengal gram	Cow gram	Lentil
Tryptophane	Soya bean	Black gram	Cow gram	Khesari	Green gram
Histidine	Khesari	Black gram	Lentil	Red gram	Horse gram

TABLE VI

Respective merits of different pulses

——	Total protein	Biological value	Digestibility	Net protein	Cystine	Tyrosine	Tryptophane	Histidine	Total
	1	2	2	1	1	1	1	1	10
Bengal gram	1	2	2	1	..	1	1	..	8
Green gram	..	..	2	1	1	1	..	1	6
Red gram	..	2	..	1	1	..	..	..	4
Field pea	1	2	..	..	..	..	..	..	3
Lentil	1	..	2	..	1	1	1	..	6
Khesari	..	..	..	..	1	..	..	1	2
Black gram	..	2	2	1	1	1	..	1	8
Cow gram	1	2	..	..	..	1	1	1	6
Field bean	1	..	..	..	..	..	1	..	2
Soya bean	1	..	2	1	..	1	1	0	6
Horse gram	..	2	..	..	..	..	1	1	4

TABLE VII

Biological values of proteins of pulses combined with rice and also with rice and skimmed milk powder

Sources of protein in the diets at 8 per cent level of intake	Biological value for maintenance measured by balance sheet method	Digestive coefficient	Biological value for growth and maintenance by growth method	Average increase in body weight (*g*)
Series 1				
Raw milled rice+Skimmed milk powder.	80	89	1·86	12·6
Raw milled rice+Red gram .	70	81	1·26	7·4
Raw milled rice+Soya bean .	68	84	1·13	6·5
Raw milled rice+Bengal gram	66	85	1·21	6·8
Raw milled rice+Black gram.	61	82	1·12	5·9
Raw milled rice+Green gram.	59	90	1·29	7·5
Series 2				
Raw milled rice+Red gram +Skimmed milk powder.	90	87	1·49	8·3
Raw milled rice+Soya bean +Skimmed milk powder.	86	93	1·33	7·3
Raw milled rice+Bengal gram +Skimmed milk powder.	80	92	1·39	9·9
Raw milled rice+Black gram +Skimmed milk powder.	79	96	1·89	8·3
Raw milled rice+Green gram +Skimmed milk powder.	77	95	2·04	10·9

NOTES

NOTIFICATION No. F. 46-27/38, DATED THE 13TH OCTOBER 1938, OF THE GOVERNMENT OF INDIA IN THE DEPARTMENT OF EDUCATION, HEALTH AND LANDS

THE following Plant Quarantine Regulations issued by the Government of Ceylon under the Ceylon Plant Protection Ordinance, No. 10 of 1924, which came into force in that country from the 1st October, 1938, are published for general information :—

THE PLANT PROTECTION ORDINANCE, No. 10 OF 1924

Regulation made by the Governor by virtue of the powers vested in him by section 9 of the Plant Protection Ordinance, No. 10 of 1924, and by Article 93 of the Ceylon (State Council) Order in Council, 1931.

B. H. ALUWIHARE,
Acting Minister for Agriculture and Lands

Colombo, July 22, 1938

REGULATION

The regulations set forth in the Schedule to the Plant Protection Ordinance, No. 10 of 1924, as last amended by regulation published in *Gazette* No. 8276 of March 12, 1937, are hereby further amended with effect from the 30th day of September, 1938, by the substitution, for the regulations contained in Part I of that Schedule, of the following new regulations :—

" 1. (1) No person shall import any plant into Ceylon through any port other than the port of Colombo or the port of Talaimannar : Provided that any of the following articles may be imported through any port, namely, onions, gingelly seed, dried turmeric, tamarind, " Karanai " roots, ground nuts, paddy, gram, dhal and other pulses, dried chillies, curry stuffs, or other culinary seed.

(2) No person shall import or land a living specimen of any insect or invertebrate animal not already known to exist in Ceylon without the written permission, previously obtained of the Director of Agriculture : Provided that the Director of Agriculture or the Director, Colombo Museum, may make such importations as may be required for scientific investigations.

2. *Prohibitions and Restrictions.*—No person shall import or land—

(*a*) any seed or plant of any species of *Hevea* grown in the Western Hemisphere ;

(*b*) except under a permit in writing from the Director of Agriculture any seed or plant or any species of *Hevea* grown in the Eastern Hemisphere ;

(*c*) any tea seed, directly or indirectly, from any place in India, except in such quantities as may be necessary for experimental purposes and except under and in accordance with the terms and conditions of a permit in writing from the Director of Agriculture ;

(*d*) any coconut plant ;

(*e*) any coconut in husk, through any port other than the port of Colombo ;

(*f*) the seed of cotton of any species of *Gossypium*, through any port other than the port of Colombo ;

(*g*) any seed, or unginned cotton or raw ginned cotton of any species of *Gossypium* grown in the Western Hemisphere, through any port other than the port of Colombo or from any port other than Bombay, or except with a certificate of fumigation or disinfection or both fumigation and disinfection from the Collector of Customs at Bombay ;

(*h*) except under a permit in writing from the Director of Agriculture, any living part of the cassava plant, *Manihot utilissima.*

3. (1) No person shall import any fresh fruit into Ceylon without a licence issued by the Director of Agriculture, or by an officer of the Department of Agriculture authorised in that behalf by the Director, or otherwise than in accordance with the terms and conditions of such licence.

(2) No licence shall be issued for the import of fresh fruit from any country in which the Mediterranean Fruit Fly (*Ceratitis capitata*) or any other pest of fruits which has not become established in Ceylon is known or suspected to exist unless the Director of Agriculture is satisfied that either before export from such country or during transit to Ceylon the fruit is so treated as to ensure that such pest, in all its stages, is effectively destroyed.

(3) Every licence issued under this regulation shall—

(*a*) specify the country from which the fresh fruit may be imported ;

(*b*) be valid for the period specified in the licence ;

(*c*) be subject to the condition that it may be withdrawn by the Director of Agriculture at any time prior to the expiry of that period by written notice addressed to the holder of the licence ;

(*d*) be subject to such other special conditions as may be set out in such licence by or by the authority of the Director of Agriculture ; and

(*e*) be in the form set out hereunder :—

"THE PLANT PROTECTION ORDINANCE, No. 10 OF 1924

Licence to Import Fresh Fruit

Under regulation 3 of the regulations set forth in Part I of the Schedule to the Plant Protection Ordinance, No. 10 of 1924, as amended by regulation published in *Gazette* No. ———— of ————, ———— (name) ———— of ———— (place) ———— is hereby licensed to import the undermentioned varieties of fresh fruit from—

———————————————

———————————————

———————————————

———————————————

This licence expires on ————————————————

This licence is subject to the condition that it may be withdrawn by Director of Agriculture at any time prior to the date set out above by written notice addressed to the holder of this licence.

This licence is further subject to the special conditions set out overleaf.

————————,

(for) *Director of Agriculture*

———— (date) ————"

(4) No person shall land any fresh fruit at any port other than the port of Colombo, and no person shall land such fruit at Colombo, unless he has satisfied the Principal Collector of Customs that such fruit was grown in and consigned from the country specified in the licence issued to that person.

4. *Inspection, Fumigation, and Disinfection.*—(1) All living imported plants, coconuts in husk, and the seed of all species of *Gossypium*, shall, before passing out of the Customs, be examined by the Inspector in charge of the Colombo Fumigatorium, together with the packings, cases, pots or coverings in which they may be packed : Provided that this paragraph shall not apply to potatoes, onions, turmeric, culinary seed, edible vegetables, and the seed of such vegetables and the seed of any ornamental plant.

(2) Every imported plant, which on inspection is found or suspected to be infected with any pest or disease, shall be subjected to fumigation or disinfection, or both fumigation and disinfection, as may be deemed necessary by the Inspector : Provided that the Director of Agriculture, by notification published in the *Gazette*, may direct, from time to time, that all imported plants of any species or genus, or all plants of any specified species or genus imported from any specified part of the world, shall be subjected to

fumigation or disinfection or both fumigation and disinfection; and after the publication of any such notification all consignments of the plants referred to therein shall be subjected to fumigation or disinfection or both fumigation and disinfection, as the case may be.

(3) Where fumigation or disinfection is necessary, such fumigation or disinfection shall be carried out at the Colombo Fumigatorium.

(4) The Director of Agriculture may order that any plant which has been fumigated or disinfected shall be grown for a period of quarantine in special nurseries provided or approved by him for that purpose.

(5) Every plant which is to be fumigated or disinfected under this regulation shall, after it is landed at the Customs premises, be conveyed to the Fumigatorium under Customs supervision at the expense of the consignee or his agent.

(6) As soon as possible after the receipt of any imported plant or package of imported plants at the Fumigatorium such plant or package shall be examined by the Inspector and fumigated or disinfected or both fumigated and disinfected, as the circumstances may require.

(7) After examination and any necessary treatment, the articles shall be delivered to the consignee together with a certificate showing that they have been dealt with as required by this regulation.

(8) No person shall remove any article from the Fumigatorium until he has obtained the certificate referred to in paragraph (7).

(9) The certificate referred to in paragraph (7) shall not be granted until all fees due in respect of supervision and fumigation have been paid in such manner as the Principal Collector of Customs may direct.

(10) Fumigation or disinfection shall be carried out at the risk of the consignee, and the consignee or his agent shall be in attendance during the process of unpacking the articles for inspection, fumigation, or disinfection and of repacking them thereafter, and shall provide the labour necessary for handling the articles during such processes.

(11) Where any plants are sent to Ceylon through the Post Office from a place beyond Ceylon the plants shall be conveyed to the Fumigatorium under the supervision of the Postal Authorities at the expense of the consignee or his agent and shall be examined by the Inspector and dealt with as prescribed in the foregoing paragraphs.

(12) The consignee shall pay in respect of each plant or package conveyed to the Fumigatorium—

(*a*) where it is conveyed under the supervision of the Customs Authorities, a supervision fee of Re. 1 for any period from 9 A.M. to 4 P.M., together with a further fee calculated at the rate of 25 cents per hour for any period between 4 P.M. and 9 P.M.; and

(*b*) where it is conveyed under the supervision of the Postal Authorities, a supervision fee of 50 cents for any period from 9 A.M. to 4 P.M., together with a further fee calculated at the rate of 25 cents per hour for any period between 4 P.M. and 9 P.M.

(13) The consignee shall, in addition to the fee specified in paragraph (12), pay a fee of 25 cents per package to cover the cost of fumigation or disinfection.

(14) Any imported plant which in the opinion of the Inspector cannot be cleaned by fumigation or other treatment shall, together with the packings, cases, pots or covering in which it may be packed, be destroyed at the expense of the consignee."

A LIST OF INTERNATIONAL CONGRESSES AND CONFERENCES TO BE HELD DURING THE NEXT FIVE YEARS

Name	Place	Date	Organising Body or the Secretary
1. VIIth International Congress of Genetics.	Edinburgh .	August 1939.	Prof. F. A. E. Crew, Institute of Animal Genetics, University of Edinburgh.
2. VIIth International Botanical Congress.	Stockholm . .	1940 . .	Dr. R. Florin, Riksmuseum, Stockholm 50, Sweden.
3. Congress of the International Society of Soil Science.	Germany . .	July 1940 .	Prof. F. Schucht, Invalidenstrasse 42, Berlin N. 4.
4. International Congress on Entomology.	(Not yet decided, probably Holland.)	1941 . .	..
5. Imperial Entomological Conference.	(Not yet decided)	1940 or 1941 (Not yet decided).	..
6. VIIIth International Congress of Tropical and Sub-Tropical Agriculture.	Tripoli . .	13th to 17th March 1939.	Under the auspices of the Ministry of Italian Africa. The President of the Executive Committee, VIIIth International Congress of Tropical and Sub-Tropical Agriculture, F. I. T. A., *via* Regina, Elena 86, Rome, Italy.
7. XVIIIth International Congress of Agriculture.	Dresden (Germany)	6-12th June 1939.	Dr. F. Sohn, Berlin S. W. 11, Hafenplatz 4.

NEW VICE-PRESIDENT OF THE INTERNATIONAL INSTITUTE OF AGRICULTURE, ROME

THE Permanent Committee of the International Institute of Agriculture has unanimously elected Mr. J. Clyde Marquis, Delegate of the United States Government, as Vice-President of the Institute in succession to Dr. J. J. L. van Rijn, Delegate of the Netherlands Government, whose three-year term of office has just expired.

RECENT PUBLICATIONS OF THE IMPERIAL AGRICULTURAL BUREAUX

Annual Reports of the Executive Council of the Imperial Agricultural Bureaux

List of Agricultural Research Workers in the British Empire, 1937*

OBTAINABLE FROM THE SECRETARY, EXECUTIVE COUNCIL, IMPERIAL AGRICULTURAL BUREAUX, 2, QUEEN ANNE'S GATE BUILDINGS, LONDON, S. W. 1, AND FROM H. M. STATIONERY OFFICE, LONDON, W. C. 2

The Journal of Dairy Research

Published by the Cambridge University Press on behalf of the Committee of Management. First issued in November, 1929.

	s.	*d.*
Volumes I to IV (each two parts)	25	0
Single parts	15	0
Volumes V to IX (each three parts)	25	0
Single parts	10	0

I. OBTAINABLE FROM THE IMPERIAL BUREAU OF SOIL SCIENCE, ROTHAMSTED EXPERIMENTAL STATION, HARPENDEN, HERTS

Soils and Fertilisers

A comprehensive abstract journal of soil science published six times yearly.

	British Commonwealth		Foreign	
	s.	*d.*	*s.*	*d.*
Ordinary edition	20	0	25	0
Special edition (printed one side only)	25	0	30	0
Both editions	40	0	50	0
Single copies, ordinary edition only	5	0	5	0

Discontinued Series

The following series of multigraphed periodicals have now been incorporated in Soils and Fertilisers. Annual sets (some incomplete) are obtainable at the prices given below.

Publications relating to Soils and Fertilisers (monthly) 1935 (8 issues) 6*s.*; 1936 (10 issues) 7*s.* 6*d.*; 1937 (10 issues) 7*s.* 6*d.*

Monthly Letters. 1935 (10 issues); 1936 (12 issues); 1937 (11 issues) 4*s.* per annum.

Recent Developments in Soil Analysis (quarterly), Complete Sets, 8*s.*

---

* 1938 Edition in preparation.

Occasional Papers

	s.	d.
Technical Communications—		
37. Soil Structure, by E. J. Russell	2	0
Annual Report for the years 1929-30 to 1937-38 . . . each	0	6
Bibliographies—		
Bibliography on Coffee	2	0
Catalogue of Journals and Periodicals in the Library of Rothamsted Experimental Station	2	0
Special Publication—		
The Katamorphism of Igneous Rocks under Humid Tropical Conditions by the late Sir J. B. Harrison	5	0
Bibliography of Soil Science, Fertilizers and General Agronomy, 1934-37	25	0

II. Obtainable from the Imperial Bureau of Animal Health, Veterinary Research Laboratory, New Haw, Weybridge, Surrey

Abstracting Journal

	s.	d.
The Veterinary Bulletin—		
1931. Vol. I. Quarterly (1st Number, April)	7	6
Annual subscription	20	0
Subsequent Volumes. Monthly (1st Number, January) . . .	5	0
Annual subscription (postage paid) (Back numbers still available) . .	40	0

Indexing Publication

Index Veterinarius. First issue April, 1933. Annual subscription (postage paid). Volumes I to III mimeographed, Volume IV onwards printed (Vols. I—V issued quarterly. Vol. VI onward issued half yearly) (Back numbers still available).	100	0

Occasional Papers

Review series—		
No. 1. Bovine Mastitis by E. M. Peterson	10	0

III. Obtainable from the Imperial Bureau of Animal Nutrition, Rowett Research Institute, Bucksburn, Aberdeen

Journal

	s.	d.
Nutrition Abstracts and Reviews. (Issued under the direction of the Imperial Agricultural Bureaux Council, the Medical Research Council and the Reid Library)		
Subscription per Volume of 4 numbers	42	0
Per single number	13	0

Occasional Papers

Technical Communications—		
10. Table of Composition of Foods giving Energy, Value, Protein, Fat, Carbohydrate, Calcium, Phosphorus and Iron Content of Some 300 Foods Commonly used in Great Britain and Compiled for Use in the Analysis of Dietary Surveys	1	0
Occasional Communications—		
2. Etiology of Endemic Goitre		

IV. Obtainable from the Imperial Bureau of Plant Breeding and Genetics, Plant Breeding Institute, School of Agriculture, Cambridge

Journal

Plant Breeding Abstracts—

	s.	d.
Quarterly. Annual Subscription	*25	0
Single copy	7	6
Volume I (Nos. 1, 2 and 3 out of print), No. 4 available	7	6
„ II Out of print	..	
„ III and IV (Nos. 1, 2 and 4 out of print), No. 3 available, each	7	6
„ V (No. 2 out of print), Nos. 1, 3, 4 available	17	6
„ VI and VII (complete), each	20	0
Numbers printed on one side of paper	30	0

Occasional Papers

Indexes to Plant Breeding Abstracts—		
Subject Index to Vols. I to V of Plant Breeding Abstracts	5	0
Subject Index to Vols. VI and VII of Plant Breeding Abstracts	2	6
Supplements to Plant Breeding Abstracts—		
Summary of Reports received from Countries exclusive of the British Empire, 1928-31. Supplement I	2	6
Summary of Reports received from Stations in the British Empire, 1932-35. Supplement II	5	0
Technical Communications—		
Vernalization and Phasic Development of Plants (Joint Publication with the Imperial Bureau of Pastures and Forage Crops)	10	0
Bibliographical Monographs—		
Tobacco Breeding Bibliography	1	0

V. Obtainable from the Imperial Bureau of Pastures and Forage Crops, Welsh Plant Breeding Station, Agricultural Buildings, Alexandra Road, Aberystwyth, Wales

Journal

	s.	d.
Herbage Abstracts—		
Vol. 7, 1937 (printed both sides)	15	0
Vol. 7, 1937 (printed one side only)	20	0
Vol. 8, 1938 (published price)	25	0
Vol. 8, 1938 (Price in Great Britain and British Commonwealth)	20	0
Herbage Reviews—		
Vol. 5, 1937	10	0
Vol. 6, 1938	†15	0

* 20*s.* to subscribers in the British Commonwealth.

† A reduction of 5*s.* will be given when Herbage Abstracts is also ordered.

Occasional Papers

	s.	d.
Bulletin—		
Erosion and Soil Conservation*	5	0

VI. Obtainable from the Imperial Bureau of Horticulture and Plantation Crops, East Malling Research Station, East Malling, Kent

	s.	d.
Journal		
Horticultural Abstracts. A quarterly abstract publication of current horticultural literature.		
Vol. I. First issued, March, 1931. No. 2, single copy . . .	1	6
Vol. II. Nos. 1, 2 and 3 out of print. No. 4, single copy . . .	1	6
Vols. III to VII, each (single copy 4*s.*)	15	0
Vols. VIII and subsequent volumes. Annual subscription . . .	†25	0
Single copy	6	6
Technical Communications		
10. Plant Injection for Diagnostic and Curative Purposes. 1938. W. A. Roach	5	0
Occasional Papers		
5. Frameworking of Fruit Trees. R. J. Garner and W. F. Walker .	1	0
Proceedings of First Imperial Horticultural Conference, 1930—		
Part II. Papers on the application of Science to Horticulture. 1931. 2*s.* Out of print, but the following separates are available, each .	0	3

Field Experiments in Certain Tropical and Sub-Tropical Crops in West Africa (Dr. E. J. Martin and W. H. Beckett).

Fruit Products and Associated Problems (Professor B. T. P. Barker).

Some Physiological Considerations in Horticulture (Professor V. H. Blackman).

Plant Physiological Work in the Tropics: Some of the Problems, with Special Reference to Cocoa and some Possible Lines of Attack (Dr. T. G. Mason and Dr. E. J. Maskell).

Soil and Survey Work as a Basis for Fruit Production in Irrigated Areas (Professor A. J. Prescott).

	s.	d.
Part III. Papers on Progress in Fruit Storage Methods, 1931, 2*s.* 6*d.* Out of print, but the following separates are available, each . . .	0	3

Factors Influencing the Storage Qualities of Fruit (Dr. T. Wallace).

The Present Position of the Bitter-Pit Problem in Australia (W. M. Carne, H. A. Pittman and H. G. Elliott).

The Behaviour and Diseases of the Banana in Storage and Transport (Dr. C. W. Wardlaw and Dr. L. P. McGuire).

Problems of Storage and Transport (E. A. Griffiths).

Fruit Transport Problems in Canada (R. L. Wheeler).

* Joint publication of bureaux of Soil Science and Pastures and Forage Crops.

† 20*s.* a volume or 5*s.* a number to subscribers in the British Commonwealth.

The Infection and Invasion of the Apple Fruit by Fungi in Relation to the Problem of Storage (Dr. A. S. Horne).

Experiments on the Preservation of Citrus Fruits (Dr. W. J. Young and F. M. Read).

Other Publications—

Index to Volumes I—X of the *Journal of Pomology and Horticultural Science*, 1933. Compiled by Bureau, published by the Editors of the *Journal of Pomology and Horticultural Science.*

	s.	d.
Available from the Bureau	5	0
Old and new standpoints on senile degeneration, 1931. By A. P. C. Bijhouwer	0	6

VII. Obtainable from the Imperial Bureau of Animal Breeding and Genetics, Institute of Animal Genetics, University of Edinburgh, Kings' Buildings, West Mains Road, Edinburgh

Journal	s.	d.
Animal Breeding Abstract (quarterly) from Vol. 6 (1938)—		
Annual subscription	25	0
Subscribers in the British Commonwealth	20	0
Earlier Vols. from 1933, Vols. I—V. Annual subscription . . .	15	0
Occasional Papers		
Animal Breeding in the British Empire. A Survey of Research and Experiment, 1934	2	0
Also obtainable from the Bureau:		
The Genetics of the Horse, 1930. Reprinted from 'Bibliographia Genetica'	0	6
Inheritance of Productivity in Farm Stock, 1935. Reprinted from 'Empire Journal of Experimental Agriculture'	0	6
The Genetics of the Pig, 1936. Reprinted from 'Bibliographia Genetica'	2	6

VIII. Obtainable from the Imperial Bureau of Agricultural Parasitology (Helminthology), Institute of Agricultural Parasitology, Winches Farm Drive, Hatfield Road, St. Albans, Herts

Journal	s.	d.
Bibliography of Helminthology. For the years 1930, 1931, 1932, 1933— Library Edition, bound in cloth per volume	10	6
Stiff paper cover only, per volume	8	0
Helminthological Abstracts (1932 onwards). Issued in five or six parts per volume, each volume covering the literature published in a single year. Subscription per volume (payable in advance) . . .	30	0
Complete volumes bound in cloth	32	0

[Note.—From Vol. III (1934) this journal incorporates the *Bibliography of Helminthology* and is published by the Bureau instead of by the *Journal of Helminthology*.]

Other Publications		
(*j*) Helminth parasites of New Zealand. By May R. Young 19 pp.. .	4	0
Notes and Memoranda—		
11. Recent Developments in the Control of Heterodera marioni, 6 pp. .	1	0

PUBLICATIONS ISSUED BY THE IMPERIAL INSTITUTE OF ENTOMOLOGY, 41, QUEEN'S GATE, LONDON, S. W. 7

Bulletin of Entomological Research—

Published quarterly, and containing original articles on Economic Entomology. Issued post free.

	s.	d.
Annual Subscription (payable in advance)	30	0
Subscription to current volume received after 30th June	36	0
Separate parts	9	0
Back Volumes—I (1910)—X (1919)	20	0
XI (1920)—XXIII (1932)	25	0
XXIV (1933) *et seq.*	37	6
Bound Volumes (extra to above prices)	6	0
Binding cases only	3	6

Reprints of some of the papers published in this Journal are available. Prices on application.

Review of Applied Entomology—

Consisting of abstracts or reviews of all current literature on Economic Entomology throughout the world. Published monthly in two series :—

Series 'A' dealing with insect and other Arthropod pests of cultivated plants, forest trees and stored products of animal and vegetable origin.

Series 'B' dealing with insects, ticks, etc., conveying disease or otherwise injurious to man and animals. Issued post free.

	Series 'A' s.	Series 'A' d.	Series 'B' s.	Series 'B' d.
Annual Subscription (payable in advance)	30	0	15	0
Subscription to current volume received after 30th June	36	0	18	0
Separate parts	3	0	1	6
Annual Subject Index (when sold separately)	6	0	3	0
Subject Index—Vols. I—III	5	0	I—X 10	0
Back Volumes—Vols. I (1913)—VII, per volume	15	0	10	0
Vols. VIII (1920)—XXII (1934), per volume	24	0	12	0
Vol. XXIII (1935) *et seq.* per volume	42	0	21	0
Bound Volumes (extra to above prices)	5	0	5	0
Binding cases only	3	6	3	6

The index to the current volume is not published until April (Series 'B') or August (Series 'A') of the following year.

Zoological Record—Part Insecta—

Published annually about July in each year and containing as complete a record as possible of the literature of the previous year, chiefly from the systematic standpoint.

	s.	d.
Annual Subscription (including postage)	15	6
Back Volumes—Vols. LII (1915)—LVII (1920)	12	0
Vol. LVIII (1921) *et seq.*	15	0

Postage extra.

Some of the Sections into which Volumes LXI—LXVII were divided are still available. Prices on application.

The Biological Control of an Insect in Fiji—

By T. H. C. Taylor. M.Sc. (Lond.). An account of the Coconut Leaf-mining Beetle and its Parasite Complex. Royal 8 vo. pp. X and 239 with 23 plates, 2 maps and 17 text figures. Bound in cloth. Price 12*s*. Postage, inland, 6*d*.; abroad, 10*d*. 1937.

Report of the Fourth Imperial Entomological Conference, 19th—27th September, 1935.

Royal 8 vo. 70 pp. Paper covers. Price, 4*s*. 0*d*. 1935.

Orders may be sent direct to the Assistant Director, Imperial Institute of Entomology, 41, Queen's Gate, London, S. W. 7, or through a bookseller.

PUBLICATIONS OBTAINABLE FROM THE IMPERIAL MYCOLOGICAL INSTITUTE, KEW, SURREY

Journal

Review of Applied Mycology—

	s.	*d.*
Annual Subscription, 12 monthly parts, with title-page and index (post free)	*30	0
Single part	3	0
Title-page and index	4	0

Back volumes (with the exception of Vols. I, VII and VIII, which are out of print) can be supplied, postage extra.

Occasional Publications

Annotated Account of Fungi Received at the Imperial Mycological Institute.

	s.	*d.*
List I	1	0
List II, Fasc. 1	1	0
List II, Fasc. 2	2	0
List II, Fasc. 3. General Part	1	0
Report on the Third Imperial Mycological Conference, 1934	2	0
Mycologists resident in the British Empire, 1938	1	0

* 24*s*. to subscribers in the British Commonwealth, who send their subscription direct to the Institute.

PUBLICATIONS OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH, INDIA

[Prices are inclusive of packing and Indian Postage]

1. Agriculture and Live-stock in India

ICAR. 1. A bi-monthly journal of agriculture and animal husbandry for the general reader interested in agriculture or live-stock in India or the Tropics. (Established 1931. Published in January, March, May, July, September and November. Prepayable subscription Rs. 6 or 9*s*. 9*d*. per annum. Price per part Rs. 2 or 3*s*. 6*d*.). Volumes I to VIII complete are available.

2. The Indian Journal of Agricultural Science

ICAR. 5. A bi-monthly scientific journal of agriculture and the allied sciences, mainly devoted to the publication of the results of original research and field experiments. (Established 1931. Published in February, April, June, August, October and December. Prepayable subscription Rs. 15 or 24*s*. per annum. Price per part Rs. 3 or 5*s*. 3*d*.). Volumes I to VIII complete are available.

3. The Indian Journal of Veterinary Science and Animal Husbandry

ICAR. 6. A quarterly journal for the publication of scientific matter relating to the health, nutrition and breeding of live-stock. (Established 1931. Published in March, June, September and December. Prepayable subscription Rs. 6 or 9*s*. 9*d*. Price per part Rs. 2 or 3*s*. 6*d*.). Volumes I to VIII complete are available.

4. Scientific Monographs of the Imperial Council of Agricultural Research

ICAR. 10·1 No. 1. The Fungi of India. By E. J. Butler, C.I.E., D.Sc., M.B., F.R.S. and G. R. Bisby, Ph.D. (1931). Price Rs. 6-12-0 or 11*s*.

ICAR. 10·2 No. 2. Life-histories of Indian Microlepidoptera, Second Series: Alucitidæ (Pterophoridæ, Tortricina and Gelechiadæ). By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. (1932). Price Rs. 3-4-0 or 5*s*. 6*d*.

ICAR. 10·3 No. 3. The Open Pan System of White-Sugar Manufacture. By R. C. Srivastava, B.Sc. (1935, 2nd Edition.) Price Rs. 3-2-0 or 5*s*. 6*d*.

ICAR. 10·4 No. 4. Life-histories of Indian Microlepidoptera; Cosmopterygidæ to Neopseustidæ. By T. Bainbrigge Fletcher, R.N., F.L.S., F.E.S., F.Z.S. 1933). Price Rs. 4-8-0 or 7*s*. 6*d*.

ICAR. 10·5 No. 5. The Bombay Grasses. By E. J. Blatter, S.J., Ph.D., F.L.S. and C. McCann, F.L.S. Illustrated by R. K. Bhide. (1935). Price Rs. 20-12-0 or 32*s*. 6*d*.

ICAR. 10·6 No. 6. Helminth Parasites of the Domesticated Animals in India. By G. D. Bhalerao, M.Sc. (1935) Price Rs. 7-12-0 or 13*s* 3*d*.

ICAR. 10-7 No. 7. Influence of Manures on the Wilt Disease of *Cajanus indicus* Spreng., and the Isolation of Types Resistant to the Disease. By W. McRae, M.A., D.Sc. (Edin.), F.L.S. and F. J. F. Shaw, D.Sc. (Lond.), A.R.C.S., F.L.S. (1933). Price Rs. 2-4-0 or 4*s*. 3*d*.

ICAR. 10·8 No. 8. The Silk Industry of Japan with Notes on Observations in the United States of America, England, France and Italy. By C. C. Ghosh, B.A., F.E.S. (1933). Price Rs. 4 or 6*s*. 9*d*.

ICAR. 10·9 No. 9. Mechanical Cultivation in India. A History of the Large-scale Experiments carried out by Burmah-Shell Oil Storage and Distributing Company of India, Ltd. By C. P. G. Wade. (1935). Price Rs. 3-14-0 or 6*s*. 6*d*.

ICAR. 10·10 No. 10. The Spotted Boll-Worms of Cotton (*Earias fabia* Stoll and *Earias insulana* Boisd.) in South Gujarat, Bombay Presidency. (Final report on investigations financed by the Indian Central Cotton Committee, 1923-1931). By B. P. Deshpande, M.Ag. and N. T. Nadkarny, B.Ag. (1936). Price Rs. 5-14-0 or 9*s*. 6*d*.

ICAR. 10·11 No. 11. Investigations on the Course and Distribution of the Nerves supplying Levator anguli scapuli and Rhomboideus muscles and the formation of the Phrenic Nerve in the Ox, with Observations on certain Anatomical Deviations. By H. N. Chelva Ayyangar, G.M.V.C. (1937). Price Rs. 4-10-0 or 7*s*. 9*d*.

ICAR. 10·12 No. 12. The Fungi of India, Supplement I. By B. B. Mundkur. Price Re. 1-6-0 or 2*s*. 3*d*.

ICAR. 10·13 No. 13. Further Observations on Anatomical Deviations in the Ox and Notes on certain Anatomical Freaks. By H. N. Chelva Ayyangar, G.M.V.C. (*In Press*).

5. Miscellaneous Bulletins of the Imperial Council of Agricultural Research

ICAR. 8·1 No. 1. List of Publications on Indian Entomology, 1930. Compiled by the Imperial Entomologist, Pusa. (1934). Price As. 14 or 1*s*. 6*d*.

ICAR. 8·2 No. 2. List of Publications on Indian Entomology, 1931. Compiled by the Imperial Entomologist, Pusa. (1934). Price As. 8 or 10*d*.

ICAR. 8·3 No. 3. List of Publications on Indian Entomology, 1932. Compiled by the Imperial Entomologist, Pusa. (1934). Price As. 12 or 1*s*. 3*d*.

ICAR. 8·4 No. 4. Host Plant Index of Indo-Ceylonese Coccidae. By S. Ramachandran, L.Ag. and T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S. (1934). Price Re. 1-10-0 or 2*s*. 9*d*.

ICAR. 8·5 No. 5. List of Publications on Indian Entomology, 1933. Compiled by the Officiating Imperial Entomologist, Pusa. (1935). Price As. 9 or 1*s*.

ICAR. 8·6 No. 6. Bee-keeping. By C. C. Ghosh, B.A., F.R.E.S. (3rd Edition.) (1936). Price Re. 1-14-0 or 3*s*. 3*d*.

ICAR. 8·7 No. 7. List of Publications on Indian Entomology, 1934. Compiled by the Imperial Entomologist, Pusa. (1935). Price Re. 1-2-0 or 2*s*.

ICAR. 8·8 No. 8. Selected Clinical Articles, Part I. By G. K. Sharma, G.P.V.C. and R. L. Kaura, B.V.Sc., M.R.C.V.S. (1936). Price As. 8 or 10*d*.

ICAR. 8·9 No. 9. Statistical Methods and their Application to Agronomy; A bibliography. Compiled by K. K. Guha Roy, B.A. (1936). Price Rs. 2-2-0 or 4*s*.

ICAR. 8·10 No. 10. Diseases of Sugarcane and Methods for their Control. By L. S Subramaniam. (1936). Price Re. 1-14-0 or 3*s*. 3*d*.

ICAR. 8·11 No. 11. Tables of Standard Errors of Mendelian Batios. Compiled by Swarn Singh Purewal, M.Sc., Ph.D. (Cornell) and P. Krishna Rao, L.Ag. (1936). Price As. 12 or 1*s*. 3*d*.

ICAR. 8·12 No. 12. List of Publications on the Botany of Indian Crops, Part II, for the period 1928-32, Compiled by R. D. Bose, B.Sc. (1936). Price Rs. 3-6-0 or 5*s*. 9*d*.

ICAR. 8·13 No. 13. Two New Statistical Tables based upon Fisher's '*t*'. By M. Vaidyanathan, M.A. (1936). Price As. 6 or 8*d*.

ICAR. 8·14 No. 14. List of Publications on Indian Entomology (1935). Compiled by the Imperial Entomologist, Pusa. (1936). Price Re. 1-4-0 or 2*s*.

ICAR. 8·15 No. 15. Selected Clinical Articles, Part II. By G. K. Sharma, G.P.V.C., R. L. Kaura, B.V.Sc., M.R.C.V.S., S. Ganapathy Iyer, G.M.V.C., G. S. Khan, B.Sc., and M. Y. Mangrulkar, M.Sc., M.R.C.V.S., D.T.V.M. (Edin.) (1937). Price Re. 1-4-0 or 2*s*.

ICAR. 8·16 No. 16. Indian Grazing Conditions and the Mineral Contents of some Indian Fodders. By P. E. Lander, M.A., D.Sc., F.I.C., I.A.S. (1937). Price Rs. 3-14 or 6*s*. 9*d*.

ICAR. 8·17 No. 17. A Brief Survey of some of the Important Breeds of Cattle in India. By Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S., F.N.I. (1938). Price Rs. 2 or 3*s*. 6*d*.

ICAR. 8·18 No. 18. Milk Records of Cattle in Approved Dairy Farms in India. By K. P. R. Kartha, B.A. Price Rs. 2-12-0 or 4*s*. 6*d*.

ICAR. 8·19 No. 19. A Preliminary Annotated List of the Fruit Pests of the North-West Frontier Province. By Hem Singh Pruthi, M.Sc., Ph.D. (Cantab.), F.N.I. and H. N. Batra, B.Sc., Assoc. I. A. R.I. Price Re. 1 or 1*s*. 9*d*.

ICAR. 8·20 No. 20. Report on an Enquiry into the Cultivation of Cloves in India. By A. K. Yegna Narayana Iyer, M.A., Dip. Agri. (Cantab.). Price Rs. 2-4-0 or 3*s*. 9*d*.

ICAR. 8·21 No. 21. Investigations on the Cold Storage of Mangoes. By G. S. Cheema, D.Sc., I.A.S., D. V. Karmarkar, M.Sc., Ph.D., A.I.I.Sc. and B. M. Joshi, M.Sc. (*In Press*).

ICAR. 8·22 No. 22. Report on a Village Enquiry regarding Cattle and the Production and Consumption of Milk in Seven Breeding Tracts of India. (*In Press*).

ICAR. 8·23 No. 23. The Cold Storage of Fruits and Vegetables. By G. S. Cheema, D.Sc., I.A.S. and D. V. Karmarkar, M.Sc., Ph.D., A.I.I.Sc. Price As. 10 or 1*s*.

ICAR. 8·24 No. 24. A Brief Survey of some of the Important Breeds of Cattle in India, Part II. By Col. Sir Arthur Olver, C.B., C.M.G., F.R.C.V.S., F.N.I. (*In Press.*)

ICAR. 8·25 No. 25. The Nutritive Values of Indian Cattle Foods and the Feeding of Animals. By K. C. Sen, D.Sc. Price As. 7 or 8*d*.

ICAR. 8·26 No. 26. The Progress of Agricultural Science in India during the Past Twenty-five Years. By W. Burns, C.I.E., D.Sc. (Edin.). (*In Press.*)

ICAR. 8·27 No. 27. Definition of Characteristics of Seven Breeds of Cattle of All-Inda Importance. (*In Press*).

ICAR. 8·28. No. 28. Bibliography of Soil Erosion, Part I. Indian Section, by R. M. Gorrie. (*In Press.*)

ICAR. 8·29. No. 29. Report on the Prospects of Cinchona Cultivation in India by A. Wilson, M.A., B.Sc., I. A. S. and T. J. Mirchandani, M.Sc., Ph. D. (*In Press.*)

6. Annual Report of the Imperial Council of Agricultural Research

ICAR. 12·31 Annual Report of the Imperial Council of Agricultural Research for the years 1929-30 and 1930-31. Price As. 12 or 1*s*. 3*d*.

ICAR. 12·32 Annual Report of the Imperial Council of Agricultural Research for the year 1931-32. Price As. 6 or 8*d*.

ICAR. 12·33 Annual Report of the Imperial Council of Agricultural Research for the year 1932-33. Price As. 6 or 8*d*. (Out of stock.)

ICAR. 12·34 Annual Report of the Imperial Council of Agricultural Research for the year 1933-34. Price Re. 1-8-0 or 2*s*. 6*d*.

ICAR. 12·35 Annual Report of the Imperial Council of Agricultural Research for the year 1934-35. Price Re. 1 or 1*s*. 9*d*.

ICAR. 12·36 Annual Report of the Imperial Council of Agricultural Research for the year 1935-36. Price As. 14 or 1*s*. 6*d*.

ICAR. 12·37 Annual Report of the Imperial Council of Agricultural Research for the year 1936-37. Price Re. 1-2-0 or 2*s*.

ICAR. 12·38 Annual Report of the Imperial Council of Agricultural Research for the year 1937-38. Price As. 12 or 1*s*.

7. Agriculture and Animal Husbandry in India (called Review of Agricultural Operations in India up to 1933)

ICAR. 9·29 Review of Agricultural Operations in India, 1928-29. Price Rs. 3-2-0 or 5*s*. 6*d*. (Out of stock.)

ICAR. 9·31 Review of Agricultural Operations in India, 1929-31. Price Rs. 5 or 8*s*. 3*d*.

ICAR. 9·33 Review of Agricultural Operations in India, 1931-33. Price Rs. 5-12-0 or 9*s*. 6*d*.

Agriculture and Animal Husbandry in India, 1933-34 and 1934-35—

ICAR. 13·1·35 Part I.—Crop Production. Price Rs. 4-14-0 or 8*s*.

ICAR. 13·2·35 Part II.—Animal Husbandry. Price Re. 1 or 1*s*. 9*d*.

ICAR. 13·36 Agriculture and Animal Husbandry in India, 1935-36. Price Rs. 4-10 or 7*s*. 9*d*.

8. Proceedings of the Board of Agriculture and Animal Husbandry

ICAR. 2 Proceedings of the First Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at New Delhi from the 20th to the 23rd February 1933, with Appendices. Price Rs. 5-14-0 or 9*s*. 6*d*.

ICAR. 2·2 Proceedings of the Second Meeting of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry held at Madras from the 14th to the 16th December 1936, with Appendices. Price Rs. 3-10-0 or 6*s*. 3*d*.

ICAR. 3 Proceedings of the First Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India held at Delhi from the 25th February to the 2nd March 1935, with Appendices. Price Rs. 6 or 9*s*. 9*d*.

9. Catalogue of Indian Insects

The following parts have been issued :—

ICAR. 11·1 Acrydidæ (Tettigidæ). By T. Bainbrigge Fletcher. 1921. Price As. 11.

ICAR. 11·2 Culicidæ. By R. Senior-White. 1923. Price Re. 1-10.

ICAR. 11·3 Bombyliidæ. By R. Senior-White. 1923. Price As. 8.

ICAR. 11·4 Trypetidæ (Trypaneidæ). By R. Senior-White. 1924. Price As. 8.
ICAR. 11·5 Nitidulidæ. By S. N. Chatterjee. 1924. Price As. 10.
ICAR. 11·6 Staphylinidæ. By M. Cameron. 1925. Price Re. 1-14.
ICAR. 11·7 Lasiocampidæ. By T. Bainbrigge Fletcher. 1925. Price As. 12.
ICAR. 11·8 Amatidæ (Syntomidæ). By T. Bainbrigge Fletcher. 1925. Price As. 12.
ICAR. 11·9 Zygænidæ. By T. Bainbrigge Fletcher. 1925. Price Re. 1-5.
ICAR. 11·10 Stephanidæ. By G. R. Dutt. 1925. Price Re. 1-2.
ICAR. 11·11 Brenthidæ. By Richard Kleine. 1926. Price Re. 1-2.
ICAR. 11·12 Tabanidæ. By R. Senior-White. 1927. Price Re. 1-12.
ICAR. 11·13 Cicindelidæ. By Mercia Haynes-Wood and Cedric Dover. 1928. Price Rs. 2-8.
ICAR. 11-14 Palpicornia. By A. d'Orchymont. 1928. Price Rs. 2-8.
ICAR. 11-15 Cecidomyidæ. By R. Senior-White. 1928. Price As. 7.
ICAR. 11-16 Cosmopterygidæ. By T. Bainbrigge Fletcher. 1928. Price As. 10.
ICAR. 11·17 Yponomeutidæ. By T. Bainbrigge Fletcher. 1928. Price As. 8.
ICAR. 11·18 Carabidæ. By H. E. Andrewes. 1931. Price Rs. 8-10.
ICAR. 11·19 Gyrinoidea. By Georg Ochs. 1930. Price As. 12.
ICAR. 11·20 Alucitidæ (Pterophoridæ). By T. Bainbrigge Fletcher. 1931. Price Rs. 1-6.
ICAR. 11·21 Lycidæ. By R. Kleine. 1931. Price Re. 1-2.
ICAR. 11·22 Phaloniadæ and Chlidanotidæ. By T. Bainbrigge Fletcher. 1931. Price As. 6.
ICAR. 11·23 Chalcidoidea. By M. S. Mani, M.A. (Res.), 1937. Price Rs. 3-2 or 5*s*. 6*d*.

10. Miscellaneous

VRI. 1 A Description of the Imperial Institute of Veterinary Research, Muktesar, and its Sub-station, the Imperial Veterinary Serum Institute, Izatnagar. By F. Ware, F.R.C.V.S., I.V.S. Price Re. 1-4-0 or 2*s*.

ARI. 7. 187 The Production of Cigarette Tobacco by Flue-curing. By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. and Kashi Ram. *Imp. Inst. Agri. Res., Pusa, Bull.* No. 187. Reprinted (1935). Price Re. 1 or 1*s*. 9*d*.

ICAR. 16 A Handbook of Statistics for use in Plant Breeding and Agricultural Problems. By F. J. F. Shaw, C.I.E., D.Sc., A.R.C.S., F.L.S. Price Rs. 4-6-0 or 7*s*. 3*d*.

ICAR. 7 Report on the Work of the Imperial Council of Agricultural Research in Applying Science to Crop Production in India. By Sir John Russell, D.Sc., F.R.S. Price Re. 1-14-0 or 3*s*. 3*d*.

ICAR. 18 Report on the Development of the Cattle and Dairy Industries of India. By Norman C. Wright, M.A., D.Sc., Ph.D. Price Re. 1-8-0 or 2*s*. 6*d*.

Copies of the above publications can be had from the Manager of Publications, Civil Lines, Delhi and from any of the Agents, a list of whom will be found on the inside page of the front cover. Prices are inclusive of packing and Indian postage.

Purchasers not residing in Asia should apply to the High Commissioner for India, India House, Aldwych, London.

Note.—When indenting please give only the symbol preceding the name of the publication.

Imperial Council of Agricultural Research
Instructions to Authors*

1. All manuscripts should be clean, clear and carefully revised. Only one side of the paper should be used. The original type-written copy and not a carbon copy should be sent. Capitals should be sparingly used, and all the necessary punctuations should be done in the MS. and not left over for introduction in proofs. Particular attention should be devoted to the following points :—

2. *Spelling.*—Errors creep into typescript and are apt to be missed in a cursory reading. The scientific names of plants and insects require special attention. The combinations ' upto ' and ' uptil ' are incorrect and should not be used.

3. *Use of capitals.*—(See also paragraphs 12 and 13). A simple rule is to avoid these except when they *must* be used. At present manuscripts require a good deal of correction, usually in the elimination of unnecessary capitals.

4. *Punctuation.*—A simple rule to follow is ' when in doubt, punctuate '. Most manuscripts suffer more from lack of commas than from their presence.

5. Referees have repeatedly drawn attention to various other faults some of which are as follows :—

(i) Careless arrangement of tabular matter,

(ii) Unnecessarily voluminous appendices,

(iii) Diffuseness in the text.

6. It ought to be kept in mind that research work is judged largely on the clearness of the published account. The reduction of a large amount of research data to a clear and readable paper *cannot* be accomplished at the first writing. In the first draft the author is generally arranging his own material and ideas and is writing or dictating with a view to get down every thing in some kind of order and with no eye either to the best disposition of the material or the clearest statement of the results. A second write-up is absolutely essential and in some cases it is worthwhile doing a third. The result will justify the labour spent.

7. The title of a paper should not be lengthy.

*Spare copies of these Instructions can be had on application to the Secretary, Imperial Council of Agricultural Research (Publication Section), New Delhi.

8. It is desirable that MS. should have suitable heads and sub-heads. In numbering the principal divisions of a paper, Roman numerals should be used. The use of Arabic figures and (*a*), (*b*), (*c*), etc., is generally reserved for numbering the sub-divisions coming under each head.

9. Articles submitted for publication either in the *Indian Journal of Agricultural Science* or in the *Indian Journal of Veterinary Science and Animal Husbandry* should be accompanied by abstracts for publication in *Agriculture and Live-stock in India*. Abstracts should be concise, but should be long enough to explain the matter dealt with; ordinarily no abstract should exceed 200 words.

10. When a word or line is intended to be printed in *italics* it should be underlined with a single line, in SMALL CAPITALS with two lines, in CAPITALS with three lines, and when in **antique** (heavy type) with a wavy line (~~~~).

11. In descriptive matter, numbers under 100 and all numbers occurring at the beginning of a sentence should be in words.

12. Local names for crops, technical operations, etc., should be defined where they first occur in the text, *e.g.*, *rabi* (spring crop). The use of local weights and measures should be avoided as far as possible. Vernacular names, such as *jowar*, *bajri*, should be in italics without a capital letter, and each such name where it first occurs should be followed by its scientific equivalent in brackets, *e.g.*, *jowar* (*Andropogon Sorghum*). It is usual to write the initial letters of varietal names in capitals, *e.g.*, Striped Mauritius, Dharwar-American cotton and Broach cotton.

13. Botanical and zoological names are printed in italics and should be underlined in the MS., *e.g.*, *Triticum vulgare* L.; *Diplodia Corchori* Syd.; *Pyrilla aberrans* Kirby. The International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed. The names of chemical substances should not be written with a capital letter.

14. The following and similar abbreviations may be used freely—*viz.*, *e.g.*, *i.e.*, mm. (millimetre), cm. (centimetre), grm. (gramme), mg. (milligramme), c.c. (cubic centimetre), sp. gr. (specific gravity), lb. (pound), cwt. (hundredweight), in. (inch), ft. (foot), oz. (ounce), md. (maund), sr. (seer). Other abbreviations should be used sparingly, if at all.

15. References to plates should be given within brackets, without prefixing the word " see " or " cf." in the MS. itself, and should not be left over for introduction in proofs. For example, " The parasite (Plate X, fig. 4) was present late in 1906 ".

16. The word " Table " is preferable to " Statement ", and tables should be numbered consecutively in Roman figures. Each table should have an explanation as a sub-head. It is more convenient for reference if tables can

be printed horizontally; for this purpose they should not exceed in width the printing measure of the page (5 in.). *Example*—

TABLE IV

Results of water-saving experiments on wheat (Pusa 12) at Gungapur, Haripur and Sargodha, 1916-17

Station	No. of irrigations including the preliminary watering	Yield per acre in maunds and seers		Average yield per acre	
		Grain	Straw	Grain	Straw
		Mds. Srs.	Mds. Srs.	Mds. Srs.	Mds. Srs.
Gungapur .	One	12 19½	20 10		
Haripur . .	,,	8 31	19 14	9 34	21 17
Sargodha . .	,,	8 12½	25 27½		

17. References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references. This system of referencing is the same as is used in the *Biochemical Journal* with slight modification and will be clear from the following illustration:—

> The work of Osborne and Mendel [1919, 1, 2] and Steenbock and Boutwell [1919] had indicated an association of the fat-soluble vitamin with the green parts of plants. This view was examined by Coward and Drummond [1921] who reported that vitamin A was not synthesised by etiolated shoots but that green leaves were active in its formation. Another worker [Wilson, 1922], on the other hand, found that etiolated shoots if given in sufficient quantity could supply the fat-soluble vitamin and that this factor was therefore formed in the absence of light.

REFERENCES

Coward, K. H. and Drummond, J. C. (1921). *Biochem. J.* **15**, 530

Osborne, T. B. and Mendel, L. B. (1919, 1). *J. Biol. Chem.* **37**, 187

——————— (1919, 2). *J. Biol. Chem.* **41**, 549

Steenbock, H. and Boutwell, R. (1919). *J. Biol. Chem.* **41**, 149

Wilson, J. (1922). *J. Biol. Chem.* **51**, 455

Abbreviations, as far as possible, should follow the system adopted in " A World List of Scientific Periodicals " published by the Oxford University Press.

18. Sources of information should be specifically acknowledged, so that readers may distinguish between the contributions to knowledge of the author and of others.

19. Papers should be complete when submitted for publication. As alterations and additions at the proof stage cause both additional expense and delay, they should be resorted to as little as possible. In making corrections in proofs, the recognized symbols which will be found in the " Standard Dictionary " should be used. Second (page) proofs will be submitted to authors who should return them promptly.

Illustrations

20. As the *format* of the journals has been standardized, the size adopted being crown quarto (about 7 1/8 in. × 9 5/8 in. cut), no text-figure, when printed, should exceed 4 1/2 × 5 inches. Figures for plates should be so planned as to fill a crown quarto plate—the maximum space available for figures being 5 3/4 × 8 inches exclusive of that for letterpress printing.

21. Photos or drawings for illustration should accompany the manuscript and each should bear on the reverse side the name of the paper to which it relates together with the title or legend, figure or plate number, and the size to be reproduced. When giving instructions for reduction, linear measurements are understood; thus, " half-size " means reduce to half the length and breadth, not half the area. A photograph should not be rolled up, nor pinned, and should always be packed flat. A complete list of plates and figures should always accompany the paper.

22. Line drawings should be made with clear black lines on smooth white paper, preferably Bristol board. Rough paper should be avoided. Care should be taken that all the lines are drawn firmly; scratchy or grey lines, produced by the ink being thinned down, are not permissible. Drawings should be larger than the required size. All lettering should be neatly and clearly put in, care being taken to make all lettering sufficiently large to stand reduction. The lettering used in the graphs of *The Economist* is specially commended to the notice of authors.

23. For half-tone work, copy should be made on glossy silver paper and of the same size or larger than the size required. Any photographs sent should be clear, properly exposed and with suitable contrast between the various parts of the picture. Every photograph should contain in itself something that will give the scale of the objects photographed. Where accuracy is important, this can be a tape or a foot-rule or a marked pole, but where accuracy is unimportant and merely the proportions of things have to be indicated, such indicators as a match-box, a book or the figure of a man (according to the size of the objects photographed) are sufficient.

24. For three-colour work, copy may be oil-painting, water-colour, coloured photograph or coloured transparency, and larger than the size required. In preparing copy, one should use only the primary colours, in any combination, as only inks of primary colours are used in printing. Originals can be enlarged, if necessary, but this should be avoided if possible.

25. For detailed instructions regarding preparation of illustrations, it would be of advantage to refer to Mr. C. M. Hutchinson's article on " Photographic illustrations " in the *Agricultural Journal of India*, Vol. XI, Pt. 3, July 1916, and Mr. A. W. Slater's paper on " The Preparation and Reproduction of Scientific Illustrations " in the *Proceedings of the Third Entomological Meeting*, 1919, which has been reprinted as *Bulletin No. 114 of the Agricultural Research Institute, Pusa*.

GIPD—M521 ICofAR—21-2-39—800.

NOTICE

The Indian Journal of Agricultural Science

A Bi-monthly Scientific Journal of Agriculture and the Allied Sciences, mainly devoted to the publication of the results of original research and field experiments

EDITORIAL COMMITTEE

SIR BRYCE C. BURT, C.I.E., M.B.E., B.Sc., I.A.S., *Vice-Chairman, Imperial Council of Agricultural Research*

W. BURNS, C.I.E., D.Sc., I.A.S., *Agricultural Commissioner with the Government of India*

F. WARE, C.I.E., F.R.C.V.S., F.N.I., I.V.S., *Animal Husbandry Commissioner with the Government of India*

RAO BAHADUR B. VISWANATH, F.I.C., F.C.S., *Director, Imperial Agricultural Research Institute*

J. R. HADDOW, B.Sc., M.R.C.V.S., D.V.S.M., I.V.S., *Director, Imperial Veterinary Research Institute, Mukteswar*

J. C. GHOSH, D.Sc., *Professor of Chemistry, University of Dacca, Dacca*

JAMES N. WARNER, M.Sc., *Offg. Professor of Animal Husbandry and Dairying, Allahabad Agricultural Institute, Allahabad*

S. BASU, I.C.S., *Secretary, Imperial Council of Agricultural Research*

The Editorial Committee, in the work of examining papers submitted for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

1. Editorial communications should be addressed to the Secretary, Imperial Council of Agricultural Research, Publication Section, New Delhi.

2. Contributors are entitled to receive 30 free reprints of their contributions; but additional copies can be had, provided notice is given at the time of returning the proofs. The rates for the supply of every 50 additional reprints, or part thereof, are as follows:—

As. 8 per type page, As. 15-3 per black-and-white plate when printed on one side of the paper only, Re. 1-5 per black-and-white plate when printed on both sides of the paper and Rs. 2-8 per three-coloured plate.

3. All communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

CONTENTS

(Vol. IX, Part I)

February, 1939

The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal.

Original Articles—

		Page
Studies in the Rind-hardness of Sugarcane, I. Anatomy of the Stalk and Rind-hardness (with Plate I and two text-figures)	*K. L. Khanna and Rama Rao Panje*	1
A Statistical Study of the Loss caused by Borers and Termites to Mature Sugarcane at Pusa in 1935 and 1936 (with one text-figure)	*H. S. Pruthi, M.Sc., Ph. D. (Cantab.), F. N. I. and E. S. Narayanan, M.A.*	15
The Proteins in the Rice Grain and the Development of Aleurone Layer (with Plates II-IV)	*K. Ramiah and C. Rajasekhara Mudaliar*	39
An Investigation into the Algal-flora of Paddy Field Soils of the United Provinces, I	*Rama Nagina Singh, M.Sc.*	55
On the Probability of Seasonal Migration among the Solitary Phase Individuals of *Locusta migratoria* in North-West India (with Plate V and one map)	*Y. Ramchandra Rao, M.A., F.R.E.S. and Desraj Bhatia, M.Sc.*	79
Economics of Field-scale Spraying against the White-fly of Cotton (*Bemisia gossypiperda* M. & L.) (with one text-figure)	*M. Afzal Husain, M.A. (Cantab.), I.A.S.; Kidar Nath Trehan, M.Sc. and Piare Mohan Verma, M.Sc.*	109
Notes on the Life-history and Habits of *Dacus brevistylus* Bezzi (Family Trypetidae), a Pest of *Coccinia indica* Fruits (with Plate VI)	*M. C. Cherian, B.A., B.Sc., D.I.C. and C. V. Sundaram*	127
A Review of the Literature on the Nutritive Value of Pulses	*R. K. Pal*	133

Notes—

Plant Quarantine Regulations	145
List of International Congresses and Conferences to be held during the Next Five Years	149
New Vice-President of the International Institute of Agriculture, Rome	150